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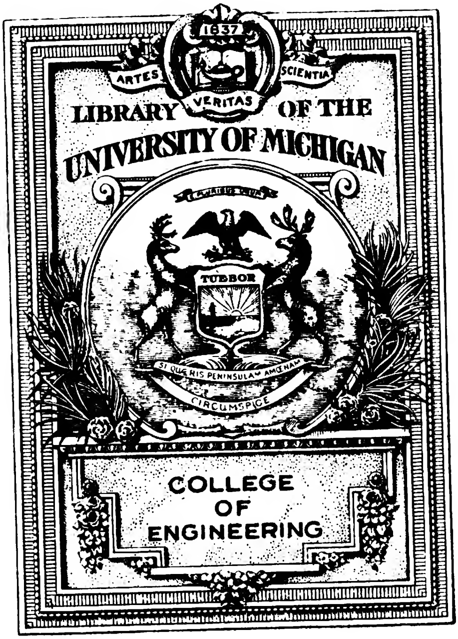
1837
ARTES
SCIENTIA
VERITAS
TUEBOR
SI QUÆRIS PENINSULAM AMŒNAM
CIRCUMSPICE

VELIE SPORT MODEL FOUR-PASSENGER CAR
Courtesy of Velie Motors Corporation, Moline, Illinois

Automobile Engineering

A General Reference Work

FOR REPAIR MEN, CHAUFFEURS, AND OWNERS; COVERING THE CONSTRUCTION,
CARE, AND REPAIR OF PLEASURE CARS, COMMERCIAL CARS, AND
MOTORCYCLES, WITH ESPECIAL ATTENTION TO IGNITION, STARTING, AND LIGHTING SYSTEMS, GARAGE EQUIPMENT,
WELDING, FORD CONSTRUCTION AND REPAIR,
AND OTHER REPAIR METHODS

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE
HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Engravings

SIX VOLUMES

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

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REMY STARTING MOTOR AND GENERATOR ON PAIGE ENGINE, SHOWING TOP VIEW

WAGNER STARTING MOTOR WITH BENDIX DRIVE EXPOSED, DESIGNED FOR GRANT CARS
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

WAGNER GENERATOR DESIGNED FOR GRANT CARS
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Foreword

THE period of evolution of the automobile does not span many years, but the evolution has been none the less spectacular and complete. From a creature of sudden caprices and uncertain behavior, it has become today a well-behaved thoroughbred of known habits and perfect reliability. The driver no longer needs to carry war clothes in momentary expectation of a call to the front. He sits in his seat, starts his motor by pressing a button with his hand or foot, and probably for weeks on end will not need to do anything more serious than feed his animal gasoline or oil, screw up a few grease cups, and pump up a tire or two.

¶ And yet, the traveling along this road of reliability and mechanical perfection has not been easy, and the grades have not been negotiated or the heights reached without many trials and failures. The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of the modern types of mechanically propelled road carriages has been a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced driver, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. The refinements in the ignition, starting, and lighting systems have added greatly to the pleasure in running the car. Altogether, the automobile as a whole has become standardized, and unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶ Notwithstanding the high degree of reliability already spoken of, the cars, as they get older, will need the attention of the repair man. This is particularly true of the cars two and three seasons old. A special effort, therefore, has been made to furnish information which will be of value to the men whose duty it is to revive the faltering action of the motor and to take care of the other internal troubles in the machine.

¶ Special effort has been made to emphasize the treatment of the Electrical Equipment of Gasoline Cars, not only because it is in this direction that most of the improvements have lately taken place but also because this department of automobile construction is least familiar to the repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the majority of the systems. In addition to this instructive section, particular attention is called to the articles on Welding, Shop Information, Electrical Repairs, and Ford Construction and Repair.

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ELECTRICAL EQUIPMENT FOR GASOLINE CARS

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ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

PRACTICAL ANALYSIS OF TYPES—(Continued)

LEECE-NEVILLE SYSTEM

Six-Volt; Two-Unit; Two-Wire

Generator. Standard shunt-wound bipolar type, combined with ignition timer and distributor driven by a worm gear on the armature shaft. The generator is mounted on the left side of the engine and is driven by the pump shaft (Haynes 1913 installation, and subsequent models to date).

It differs from the standard shunt-wound machine in that the shunt field is connected to the regulating third brush. This brush collects current from the commutator and excites the field, so that a strong shunt field is provided at comparatively low speeds. As the speed increases, the voltage supplied to the shunt field decreases, even though the total voltage between the main brushes may have increased. This weakens the field and prevents the output of the generator from increasing with the increased speed. At higher speeds it acts somewhat similarly to a bucking-coil winding in that it further weakens the field and causes the generator output to decrease still more. The closer the third brush is set to the main brush just above, the greater will be the output of the machine; moving it away from the main brush decreases the output.

Regulation. Generators of the 1915 and 1916 models are controlled by armature reaction through a third brush, the field coils receiving their exciting current from the armature through this brush. The position of the latter on the commutator is shown at *B*, Fig. 293. A slight rotation of this brush relative to the commutator changes the electrical output of the machine. As adjusted at the factory this brush is set to give a maximum output of 15 amperes at 7½ volts. (All generators for 6-volt systems are wound to produce an e.m.f. of 7½ volts, or thereabout, in order that the voltage of the generator may exceed that of the battery when the latter is fully charged. The e.m.f. of generators for 12-volt and 24-volt systems also exceeds that of their batteries in about the same proportion. Otherwise, the generator would not be able to force current through the battery.)

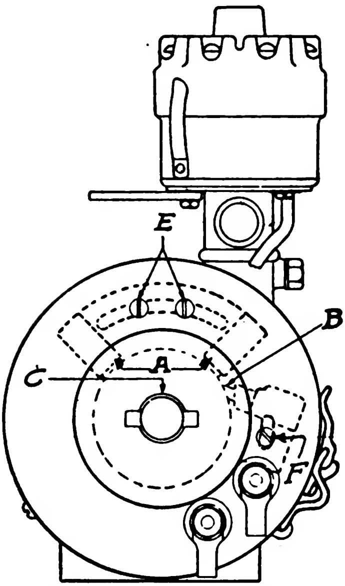

Fig. 293. Diagram of Arrangement of Brushes on Leece-Neville 6-Volt Generator

Starting Motor. The motor is of the bipolar series-wound type driving the engine through a roller chain and an over-running clutch.

Instruments. An indicating type of battery cut-out is employed, thus combining the functions of the cut-out and ammeter in one device. The details of this device are shown in Fig. 294. *O* is the winding or coil of the electromagnet of which the U-shaped bar 8 forms the magnetic circuit. At *4* is the pivoted armature, normally held in the *OFF* position as shown by a spring, when no current is passing, and adapted to be drawn against the pole pieces of the magnet when the latter is excited by the charging current. As the two-wire system is employed, the cut-out breaks both sides of the battery-charging circuit and it is provided with six current-carrying contacts on each of the sides of the circuit. Four of these, which carry most of the current, are *copper* to bronze,

Fig. 294. Details of Leece-Neville Indicator

while those that take the spark in breaking the circuit are *cophite* to iron and are actuated by a spring. The indicating target *16* is held in the *OFF* position by the spring *19* when no current is passing, and this reading appears in the opening of the panel on the cover. When the generator starts and the cut-out closes, the target is moved to bring the word *CHARGING* in the opening. The same panel also carries the three-way lighting switch controlled by buttons. The central button closes the circuit to the headlights and tail lights in the usual manner, while the upper button throws the headlights in series-parallel connection. As this doubles the resistance, it halves the voltage passing through the lamps, and they, accordingly, burn dimly. The lower button controls the cowl light over the instruments on the dash.

Wiring Diagram. Fig. 295 illustrates the Haynes 1915 installation. While two wires are employed for connecting all the apparatus, it will be noted that the storage battery and the dry-cell battery are grounded by a common ground connection. This is to permit using current from the storage battery for ignition, the corresponding ground to complete the circuit being noted at the ignition coil, close to the distributor. The connections *G* and *B* on the panel board are those of the generator and the battery to the indicating battery cut-out, the connections of three lighting switches being shown just to the right. In Fig. 296 is shown the Leece-Neville installation in White cars.

Instructions. Never run the engine when the generator is disconnected from the battery unless the generator is short-circuited, as otherwise it will be burned out in a very short time. This applies to all lighting generators except those protected by a fuse in the field circuit, in which case the fuse will be blown. The Leece-Neville generator can be short-circuited by taking a small piece of bare copper wire and connecting the two brush holders together with it. Instructions for short-circuiting other makes are given in connection with the corresponding descriptions.

Later models of the Leece-Neville generator are provided with a circuit-breaker. On the Haynes 12-cylinder models, this is mounted on top of the generator, while in some cases it is combined with the ammeter on the dash. To protect the generator and battery, there is a 5-ampere cartridge fuse under the cover of this circuit-breaker.

Fig. 295. Wiring Diagram for Leece-Neville System on Haynes Light Six

When this fuse blows out, both the generator and the circuit-breaker become inoperative. Any one of the following conditions may cause this fuse to blow out: loose or corroded connections at the battery; an open circuit in the wiring on the battery side of the cut-out; not sufficient water in the battery; output of the generator too high;

Fig. 296. Wiring Diagram of Leece-Neville System on White Cars

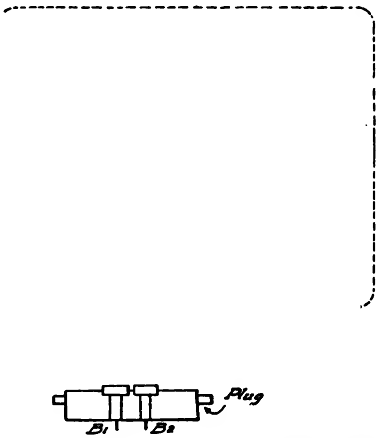

Fig. 297. Wiring Diagram of Generator and Circuit-Breaker Circuits for Leece-Neville System
Courtesy of The Leece-Neville Company, Cleveland, Ohio

allowing the main brush directly above the third brush to stick in its holder; a loose connection at the point A_2, Fig. 297; improper insulation between the wires B_1 and B_2 in the connector plug, Fig. 297. By an open circuit is meant an actual break at a connector or a terminal, or in the wiring itself, while a loose connection signifies an insecurely fastened terminal or wire, at a junction box, or at any other part of the system. If there is a short-circuit in the field winding of the generator, this also will cause the fuse to blow out.

Testing the Field Winding. While a short-circuit in the field winding of any generator is a rare fault, there are times when the trouble cannot be traced to any other part of the system. To test the Leece-Neville generator for this, connect the negative terminal of the portable testing ammeter to F_1, Fig. 297, while the positive terminal of the motor must be connected to the positive terminal of a 6-volt storage battery; the negative terminal of the battery is to be connected to the third brush when drawn from its holder. If the indication of the ammeter is above 4 amperes, there is a short-circuit in the field windings. In such a case, the generator should be returned to the manufacturers for repairs.

With the engine running, the working of the generator should be inspected from time to time. In case there is excessive sparking or "arcing" between the brushes and the commutator, examine the connections at F_1 and A_1 and see that the screws are perfectly tight, as these screws sometimes work loose and are responsible for this arcing which is destructive to the commutator. The loosening of the connections at F_1 and A_1 will have no effect on the fuse; but if the connection at A_2 loosens, the fuse will burn out. When inspecting the operation of the generator, see that the brushes are making good even contact with the commutator, and wipe away all particles of dust and grit from around the brushes and their holders. With the engine stopped, see that the brushes move freely in their holders. This should always be done where a car has been laid up for some time (before starting the engine) as the brushes, through disuse, will have a tendency to stick.

The fuse in the circuit-breaker has no effect whatever on the output of the generator, so that a larger fuse must not be inserted in case the generator is not delivering its rated output or more. The makers supply a 5-ampere fuse for this purpose, and if a fuse of

Leece-Neville Starting and Lighting Installation on the Haynes 1917 Light Six
Courtesy of Leece-Neville Company, Cleveland, Ohio

Leece-Neville Starting and Lighting System on White Cars, Model G-M
Courtesy of Leece-Neville Company, Cleveland, Ohio

heavier capacity is employed, it will cause both the circuit-breaker and the generator to burn out. This will be the case also where a "jumper" is resorted to, i.e., a piece of wire or other metal bridging the fuse clips so that the fuse is cut out of the circuit. It must be borne in mind, however, that these fuses are more or less fragile and are likely to become damaged by careless handling. A fuse whose connections have been loosened up is likely to blow out on that account, so before inserting a fuse in the clips of the circuit, it should be examined to see that the ferrules on each end of the cartridge are perfectly tight. Where a good fuse has been inserted and it blows out, the cause should be ascertained before inserting another fuse.

Regulating Brush. In case the generator output falls off as shown by its inability to keep the battery properly charged, the battery itself and all connections being in good condition, and a proper amount of day running being done to provide the necessary charging current, the trouble may be in the regulating brush of the generator. Test by inserting an ammeter, such as the Weston portable or any other good instrument with a scale reading to 30 amperes, in the line between the generator and the battery. Run the engine at a speed corresponding to 20 miles per hour, at which rate the ammeter should record a current of approximately 15 amperes. If the ammeter needle butts against the controlling pin at the left end of the scale instead of showing a reading, it indicates that the polarity is wrong, and the connections should be reversed. Should there be no current whatever, the needle will stay perfectly stationary except as influenced by vibration. If the ammeter shows a reading of less than 15 amperes, the current output of the generator may be increased by loosening the set screw holding the third brush and rotating the brush slightly in the same direction as the rotation of the armature. This should be done with the generator running and the ammeter in circuit, noting the effect on the reading as the brush is moved. To decrease the output, it should be moved in the opposite direction until the proper reading is obtained, after which the brush must be sanded-in to a good fit on the commutator. It may sometimes occur that sufficient movement cannot be given the third brush without bringing it into contact with one of the main brushes. This must be avoided by loosening the two set screws *E*, Fig. 293, and moving the main brush holder away from the third brush until there is no danger of their touching. After securing the desired adjustment, fasten the third brush in place again, stop the engine, and then reconnect the generator to the battery. Do not cut the ammeter out of the circuit while the generator is running.

To Adjust Third Brush. Before making any adjustment of the third brush when it is suspected that any trouble with the current supply is due to the generator, the output of the generator should be tested. On a car equipped with lamps totaling 250 candle power or more (this refers to White busses), the generator should produce 20 amperes. Run the engine at a speed sufficient to drive the car 15 o 16 miles per hour on direct drive and note the reading of the dash ammeter. In case the car has seen considerable service, it may be well to check the dash ammeter with the more accurate portable ammeter described in connection with other tests in previous and subsequent sections. Where the car lighting system totals 250 c.p. or over, and the ammeter reading shows more than four amperes above or below 20, the generator should be adjusted to give its rated capacity of 20 amperes—as every 15 c.p. less than 250 c.p. used on the car, lower the output of the generator by one ampere. By making the adjustments in this manner, the storage battery will be amply protected.

Before making any generator adjustments, test the storage battery with the hydrometer. Do not add any distilled water just previous to making this test unless the level of electrolyte is right down to the plates so that sufficient liquid cannot be drawn into the hydrometer; in this case, add water and charge the battery for at least one hour before making the hydrometer test. If the specific gravity of the electrolyte is 1.250 or over, and the generator is found to be delivering less than the rated lamp load, no adjustment of the generator should be made.

To increase the output of the generator, rotate the third brush in the direction of rotation of the armature; to decrease the output, move the brush against the direction of rotation. Adjustments should be made with the engine standing. Loosen the screw at the rear of the commutator housing shown at the point *F*, Fig. 293. This releases the third brush holder, and the brush may then be moved in the direction desired. It should be moved only a short distance, and the generator then should be tested until the desired output is secured. In case the third brush should come in contact with the main brush above in the course of adjustment, it will be necessary to move the main brushes. To do this, loosen the two set screws *E*, Fig. 293, and move the main brush holder far enough away from the third brush so that there is no possibility of contact between them. When the desired location is found, sand-in the third brush to the commutator and also clean the commutator with a piece of worn sandpaper as described in the section on Sanding-In the Brushes (Delco instructions); if it has been necessary to move the main brushes, they should be sanded-in also. The brush holder screws should be well tightened after making any adjustments to prevent any possibility of the vibration and jolting loosening them up and throwing the generator out of adjustment again.

Brush Replacements. Never replace any of the brushes on either the generator or starting motor with any but those supplied by the manufacturer of the system for this purpose. Motors and generators adapted for use on electric-lighting circuits are usually fitted with plain carbon brushes. These are not suitable for use on automobile generators or starting motors owing to their resistance being much higher. Due to the low voltage of electric apparatus on the automobile, special brushes of carbon combined with soft copper are usually employed. Brushes also differ greatly in hardness, and a harder brush than that for which the commutator is designed will be liable to score it badly besides producing a great deal of carbon dust, which is dangerous to the windings. This, of course, applies to all makes of apparatus and not merely to that under consideration.

Generator or Motor Failure. For failure of the generator or of the starting motor, see instructions under Auto-Lite, Delco, and Gray & Davis, bearing in mind, however, that the system under consideration is of the two-wire type, so that in using the test lamp to locate short-circuits a connection to the frame or ground is not always necessary. The short-circuit may be between two adjacent wires of different circuits. Given properly installed wires and cables, there is less likelihood of short-circuits in the wiring of a two-wire system. Defective lamps will not infrequently prove to be the cause, as, in burning out, a lamp often becomes short-circuited.

NORTH EAST SYSTEM*

Twelve-Volt, Sixteen-Volt; or Twenty-Four-Volt; Single-Unit; Single-Wire or Two-Wire, According to the Installation

Dynamotor. The dynamotor is of the four-pole type, with both windings connected to the same commutator. It is designed for installation either with silent-chain drive—as on the Dodge, Fig. 298, in which case the drive is direct either as a generator or as a motor—or with a special reducing gear and clutch for driving from the pump or magneto shaft of the engine. In the latter type, the starting switch is mounted on the gear housing, which is integral with the bedplate of the dynamotor. In this case the drive as a generator is 1½ times engine speed, while as a starting motor the reduction through the gear is approximately 40 : 1.

Fig. 298. North East Dynamotor with Silent-Chain Drive. Starting Switch Shown at Right
Courtesy of North East Electric Company, Rochester, New York

Regulation. The regulation is by means of a differential winding or bucking coil, in connection with an external resistance automatically cut into the shunt-field circuit by a relay in series with the battery cut-out. See "limiting relay", Fig. 299. The "master relay" is the battery cut-out, and the condenser is to reduce sparking at the contacts of these relays.

Protective Devices. There is a fuse in the field circuit of the generator, but fuses are not employed on the lighting circuits.

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* The voltage of any system may be determined by counting the number of cells in the storage battery, and multiplying by 2 in the case of a lead battery, or multiplying by 1¼ where an Edison battery is used.

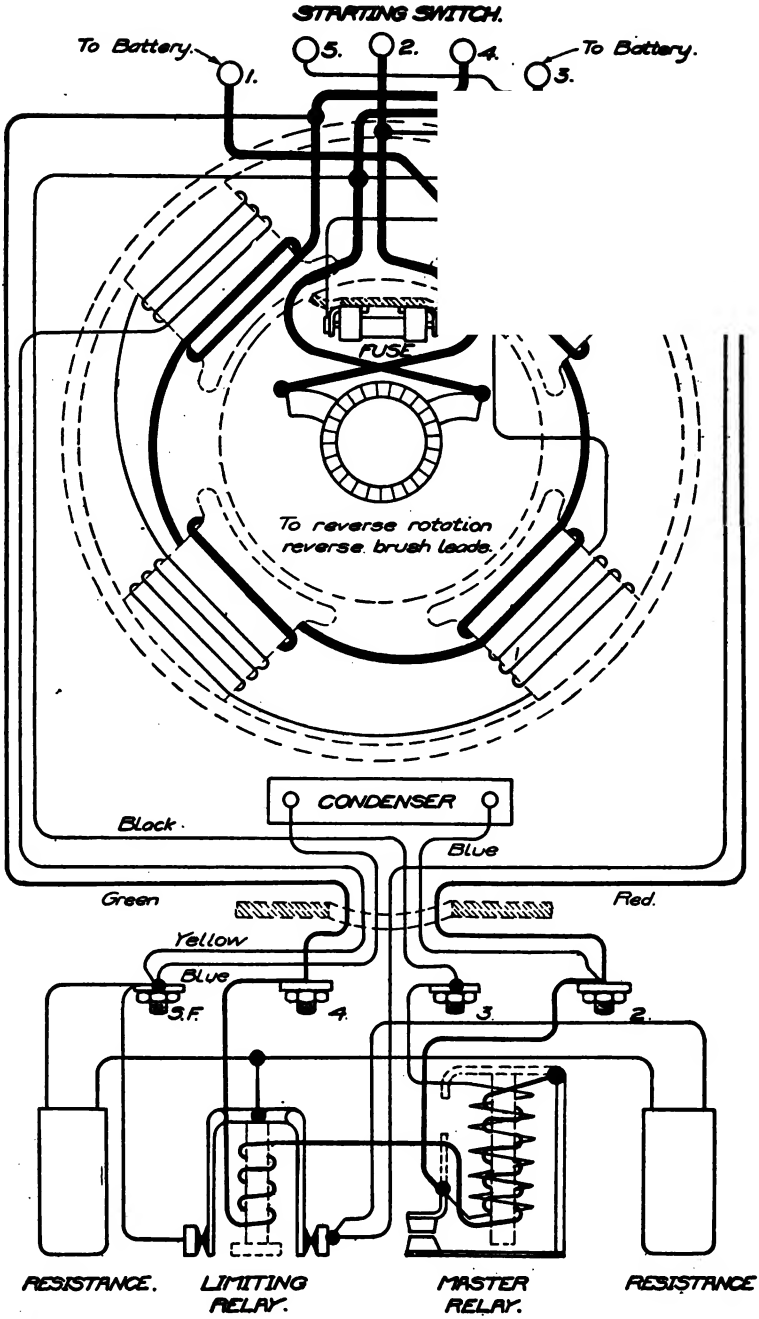


Fig. 299. Diagrammatic Section of North East Dynamotor, Showing Regulator (Limiting Relay) and Cut-Out (Master Relay)

Wiring Diagrams. A graphic diagram of the North East installation on the Dodge is shown in Fig. 300. This is a 6-cell or 12-volt system single-wire type. The sprocket on the forward end

Fig. 300. Diagrammatic Layout of North East Installation on Dodge Cars
Courtesy of North East Electric Company, Rochester, New York

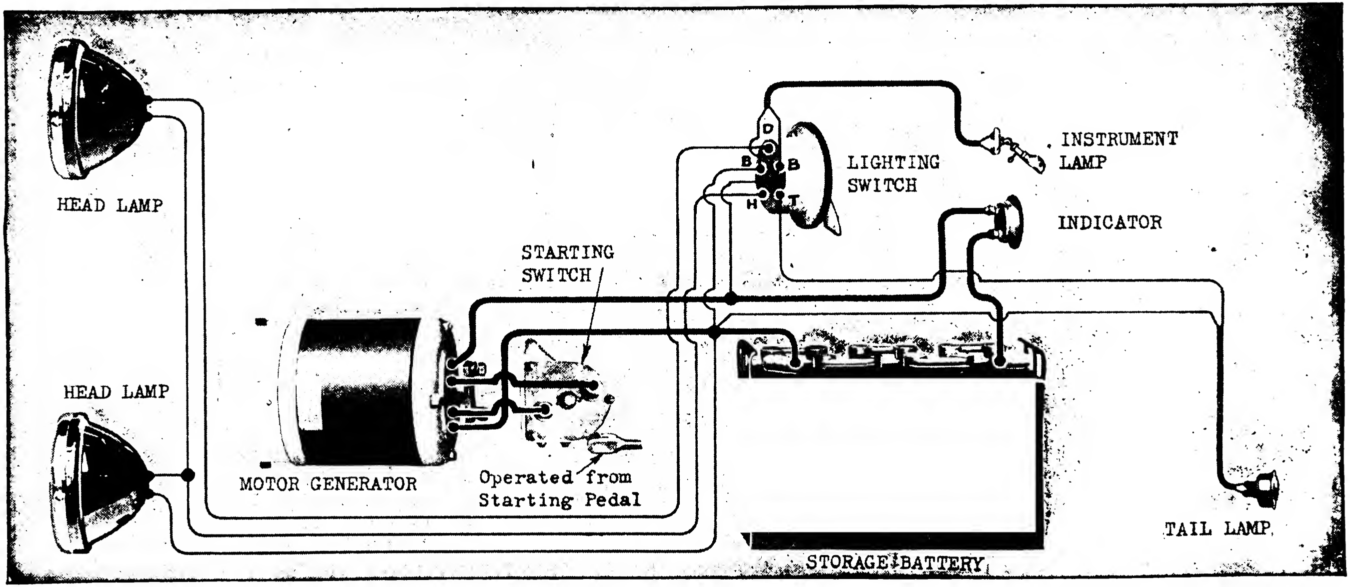


Fig. 301. Diagrammatic Layout of North East 12-Volt Installation on Krit 1915 Automobiles (14-Volt Lamps)

of the machine drives from a similar but much larger sprocket on the forward end of the crankshaft of the engine through a silent chain. The wiring diagram of the Krit 1915, Fig. 301, will be recognized as being the same as the Dodge, except for the use of two wires throughout. Fig. 302 shows the wiring diagram of an 8-cell or 16-volt system, but the battery is divided for the lighting circuits so that 8½—9-volt lamps are used, whereas 14-volt bulbs are necessary on the Dodge installation as the entire battery is used in series for lighting. The wiring of the 12-cell or 24-volt system is shown in Fig. 303. In this case the battery is divided for lighting so that 7-volt lamps are employed. Such a system is usually designated as 24—6-volt, while the previous one would be a 16—6-volt. The North East installation for Ford cars is 24—14-volt. With the exception of the Dodge, the two-wire system is employed on the installations mentioned.

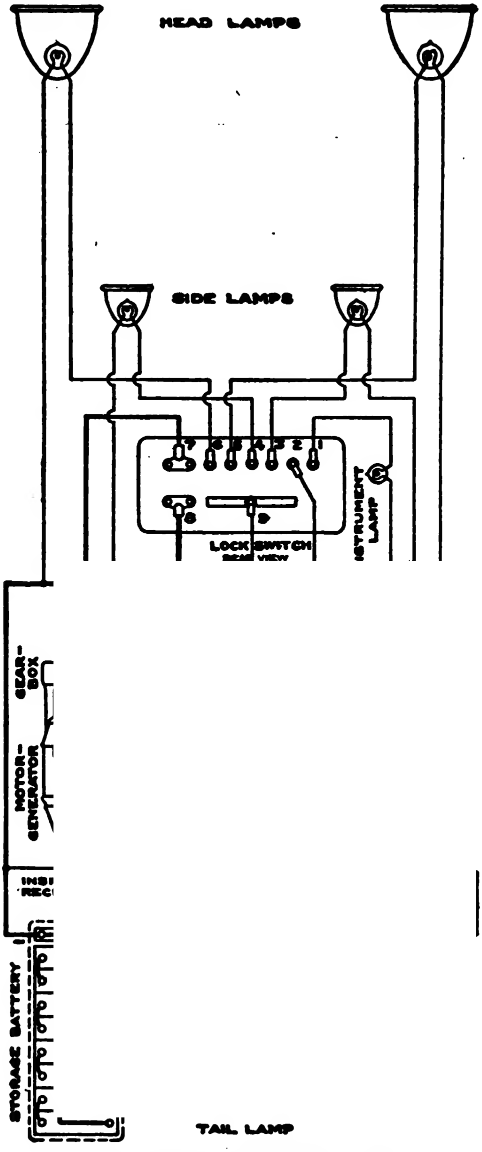


Fig. 302. Wiring Diagram for 16-Volt North East System Using 8½—9-Volt Lamps

Instructions. The indicator shows when the battery is charging or discharging and accordingly should indicate OFF when

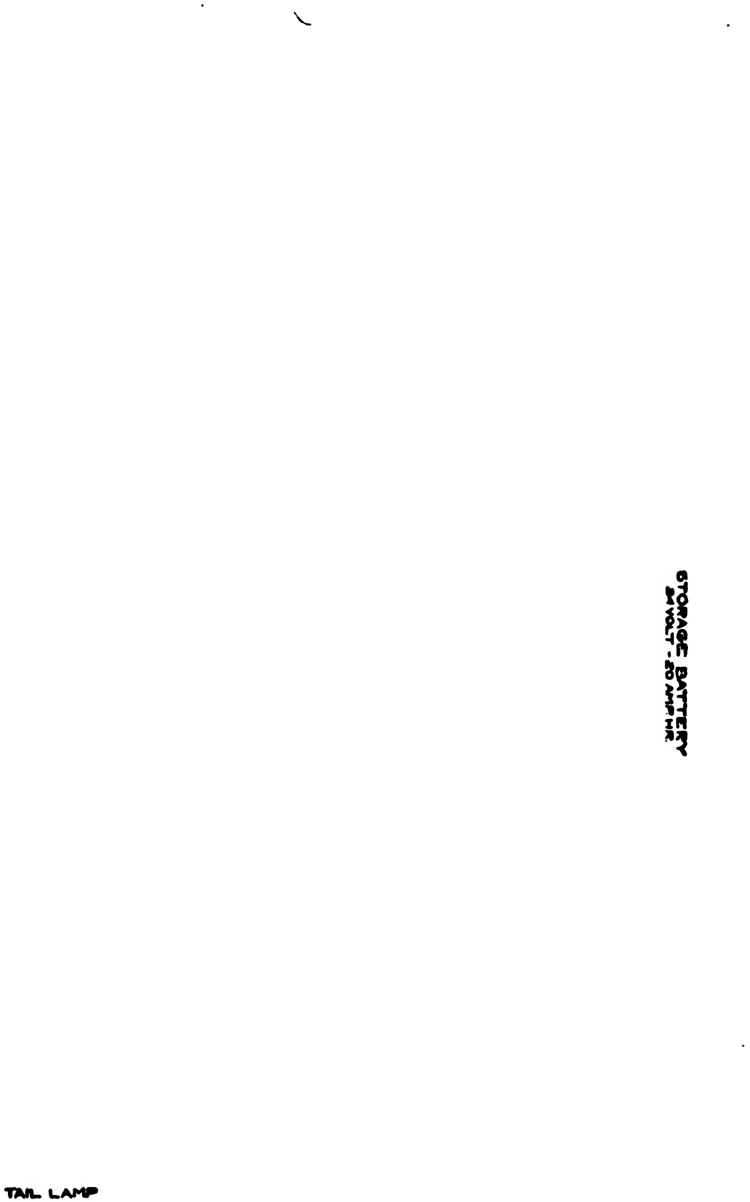


Fig. 303. Wiring Diagram for 24-Volt North East System Using 7-Volt Lamps

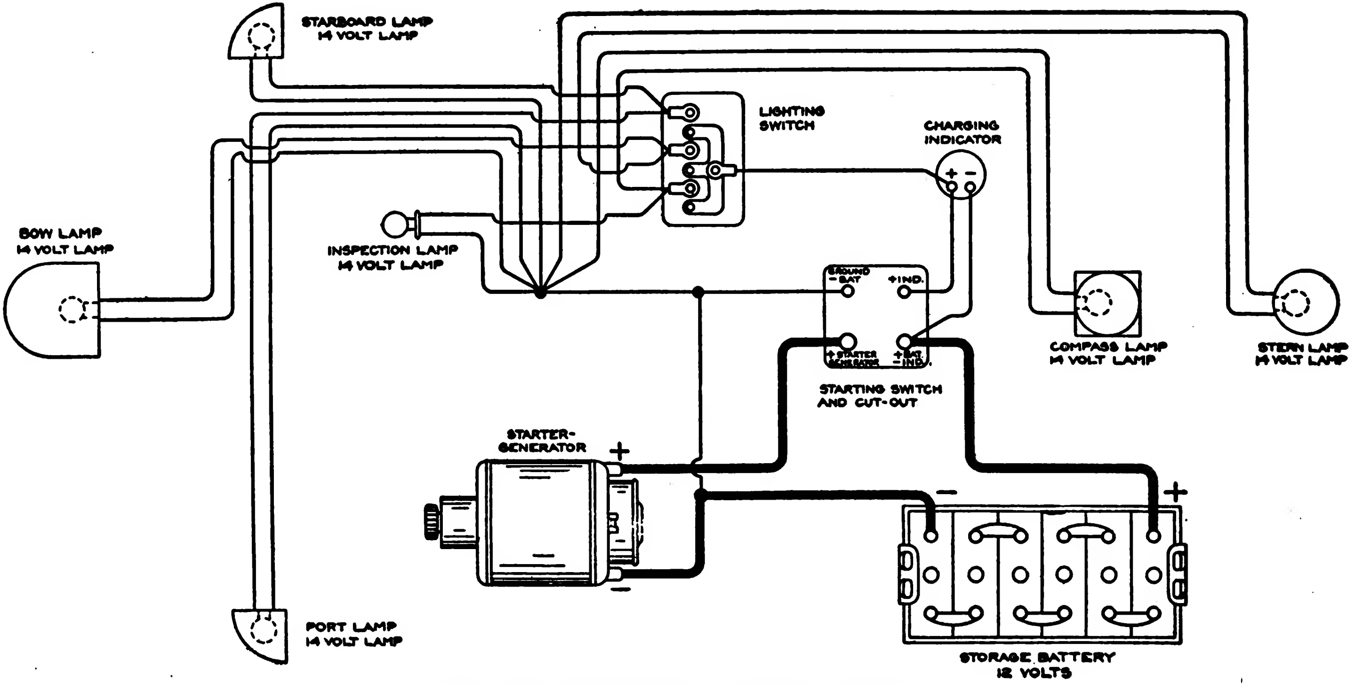
the engine is idle and no lamps are lighted. A discharge reading under such conditions would indicate the presence of a ground, short-circuit, or failure of the battery cut-out to release. Should the generator fail to charge the battery, note whether the field fuse has been blown by short-circuiting the fuse clips with the pliers or a piece of wire while the engine is running at a moderate speed. Look for cause of failure before replacing the fuse. If the fuse has not blown, see whether battery cut-out is operating; look for loose connections at generator, cut-out, and battery. If the battery is properly charged, loose connections are also most likely to be the cause of failure of the starting motor; or, any of the instructions covering brushes, commutator, etc., as given previously, may apply.

Battery Cut-Out and Regulator (*Relays*). In every case where it is necessary to make repairs on starter-generators equipped with the earlier type cut-out and regulator (relays), 1283 (12-volt), 1860 (16-volt), 2501 (24-volt), 1900 (16-volt), and 2503 (12 and 24-volt), it is advisable to replace the cut-out entirely, installing a later and improved type, 1196 (12-volt), or 1197 (24-volt and 16-volt). In order to adapt the starter-generator to the 1196 and 1197 cut-out, or relay units, it is necessary to cut out the bosses on the commutator end bearing in which the studs holding the original relay were screwed. This will provide the clearance required to prevent grounding of the nuts which secure the units to their baseboard. As a further precaution against grounding, it will be necessary to cut away that portion of the gasket retainer which would be liable to come into contact with the armature of the master relay.

Fasten down the baseboard which carries the relays by screwing the resistance unit studs into the holes which were used for the former resistance studs. Before making connections on the relay, draw tight all leads which come from inside the starter-generator so as to take up whatever slack they have; then tie them together with string to prevent their slipping back. No loose wire must be left inside the starter-generator, because of its tendency to be drawn in between the armature and the pole pieces. The connections on the four-terminal type starter-generator are made as follows:

Looking at the starter-generator from the driving sprocket end, the main terminals 1, 2, 4, and 3 of the starter-generator are considered as being numbered in anti-clockwise rotation, Fig. 304. Viewing

North East Single-Wire Starting and Lighting System on Dodge 1917 Cars
Courtesy of North East Electric Company, Rochester, New York



North East Two-Wire Starting and Lighting Installation
Courtesy of North East Electric Company, Rochester, New York

the relay unit as mounted on the starter-generator with the larger, or master relay, at the left, the four binding posts *a*, *b*, *c*, and *d* are designated from left to right in the same illustration. To relay binding post *a*, connect lead (red) coming from starter-generator terminal 2. To relay binding post *b*, connect lead (black) coming direct from starter-generator terminal 3. To relay binding post *c*, connect lead (green) from starter-generator terminal 4. To relay binding post *d*, connect lead (yellow) from starter-generator shunt-field coils. It is always advisable to check the identity of the leads by inspection and test.

In order to make a positive distinction between the *d* lead and the *b* lead, both of which are in electrical connection with the starter-generator terminal 3, the following test should be made: Using the test-lamp outfit, send current from starter-generator terminal 3, through each of these wires in turn, and note appearance of the lamp. When the direct lead (*b* lead) is in circuit, the lamp will burn with full brilliance, but when the *d* lead, which includes the starter-generator shunt-field coils, is in circuit, the lamp will be noticeably dimmer.

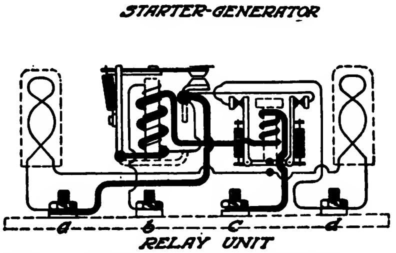


Fig. 304. Internal Wiring Diagram for North East Model "D" Starter-Generator

Five-Terminal Type Unit. The connections on the five-terminal type generator-starter unit are made as follows: Looking at the starter-generator, Fig. 305, from the driving sprocket end, the main terminals 1, 5, 2, 4, and 3, respectively, of the unit are numbered in anti-clockwise rotation (to the left). Viewing the relay unit as mounted on the starter-generator with the master relay at the left, the four binding posts *a*, *b*, *c*, and *d* are designated from left to right as shown in the illustration. Proceed with the instructions as given for the four-terminal type starter-generator as given. The new type relays 1196 and 1197 are regularly furnished with local connections, as shown in Fig. 304, but it will be necessary to make the following alterations when applied to the five-terminal type starter-generator, so that the relay connections will conform to the diagram in Fig. 305. Remove the jumper lead that connects the frame of the master relay to the rear contact terminal on the limiting relay; remove from relay binding post *a* the left-hand resistance-unit lead. Lengthen this lead by splicing a piece of the same kind of wire to it, and solder it to the limiting relay contact terminal, from which the jumper has been removed. To this terminal must also be soldered the lead coming from starter-generator terminal 5. (In some starter-generators this lead includes the field fuse.)

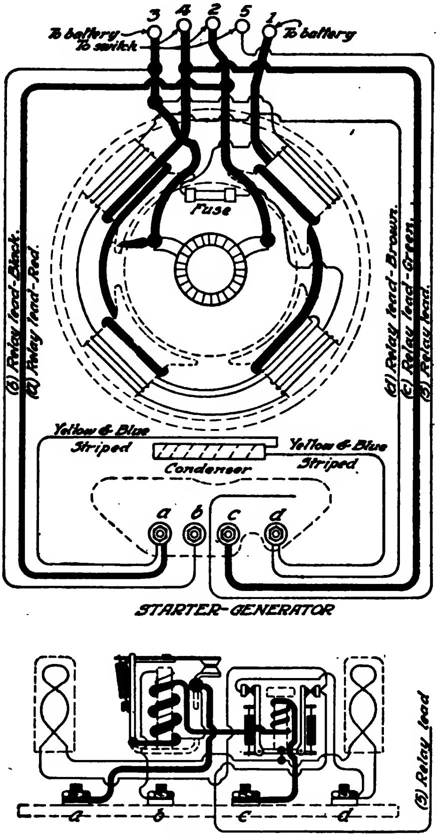


Fig. 305. Internal Wiring Diagram for Model "B" Starter-Generator

The condenser in the early models is mounted between the field coils. One condenser lead must either be connected to the relay binding post *a* as shown in either Fig. 304 or Fig. 305 or be spliced to the wire leading to it. The other condenser lead must either be connected to the relay binding post *d* or spliced to the shunt-field wire leading to it.

Fig. 306. View of Essential Parts of North East Starting Switch
Courtesy of North East Electric Company, Rochester, New York

Starting Switch. When its operation indicates that the contactor blades have worn, the starting switch should be dismounted, and, if necessary, new blades should be inserted. To disassemble the switch, proceed as follows: (1) Remove the spring 2265, Fig. 306, on the switch case 2365; (2) remove the cotter pin from the collar 2416; (3) withdraw the shaft and lever 2401, together with the spring 1818; (4) remove the three screws which hold the cover 2404 in place, and remove the cover; (5) remove the stop 2457; and (6) disconnect the spring 1813 from the arm of the ratchet and remove the contactor member 2344.

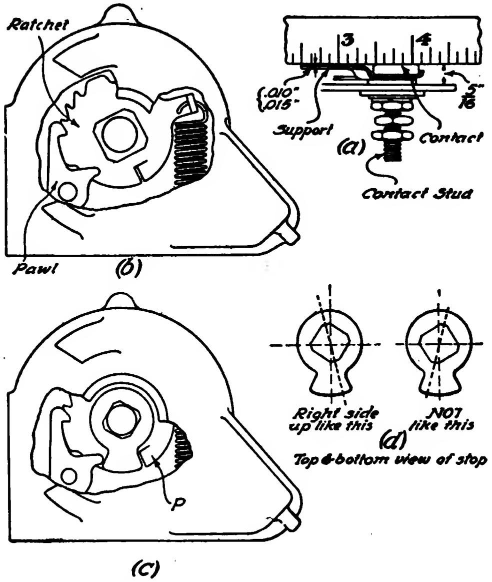


Fig. 307. Assembly of Starting Switch
Courtesy of North East Electric Company, Rochester, New York

If, upon inspection, the contacts are found to be in such a condition that their renewal is necessary, make a replacement of the entire cover member 2404 and the entire contactor 2344. Before placing these new parts in the switch, the following points should receive careful attention: the front edges of the contact blocks should be slightly rounded so as to eliminate the possibility of these edges catching on each other when the switch is being operated. The supports on the cover must be adjusted so that they lie parallel with the faces of the contact blocks.

The upper surfaces of the supports must be .010 to .015 inch lower than the contact surface of the block. Care should be taken that the upper surface of the contact blocks are $\frac{5}{16}$ inch above the inner surface of the cover. A small steel straightedge laid upon the face of the contact block and extended over the supports, as shown in Fig. 307 (*a*), will serve as a means of checking these dimensions.

Before placing in service, the contact surfaces must be carefully cleaned and lubricated with a very small quantity of vaseline. To reassemble the switch: (1) Connect the spring 1813, Fig. 306, to the arm of the ratchet; (2) place the contactor member 2344 in the switch case in such a position that the ratchet will lie against the pawl 1830; and (3) hold the switch case in the left hand, lever side up, and insert the right forefinger through the hole in the switch case and introduce the pawl into the first notch of the ratchet, Fig. 307 (*b*); (4) hold these parts carefully in position and replace the cover 2404, Fig. 306, fastening it to the switch case by means of the three screws; (5) insert the stop through the hole in the switch case and replace it upon the ratchet plate in such a position that the elongated portion of the stop will lie between the raised projection which is found on the ratchet plate and the end of the short lever on the pawl as shown in Fig. 307 (*c*). It is very important that the stop be placed in the switch right side up, Fig. 307 (*d*) illustrating the proper method of doing this. (6) Place the spring on the shaft and replace the shaft in the switch, taking care while entering the shaft not to disturb the arrangement of any of the switch parts; (7) replace the collar and the cotter pin; and (8) connect the spring 2265 with the lug on the switch case. A drop of light oil should be applied to the bearing point at each end of the switch shaft 2401.

Switch Tests. To determine whether the switch has been assembled correctly, pull the lever through the full length of its stroke and allow it to return slowly to its initial position. If the switch is properly assembled, three distinct clicks will be heard while the lever is being moved through its stroke, and a snap will occur just before the lever comes back to its initial position. The switch should be tested electrically, as follows:

Ground Test. Using the lamp-test set as shown in Fig. 263 and following Part V, hold one contact point on the switch case and then connect the other to the two contact studs. The test lamp will not light unless there is a ground.

Operation Test. Hold one of the test points in contact with each of the two studs, and turn the lever through its stroke. If the switch is in proper working condition, the test lamp will light up just after the first click of the switch and continue to burn until the final snap occurs.

TABLE V

Characteristics of North East Starting and Lighting Apparatus

Approximate Elect
Master
Cuts in Pos. Am
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1250 r.p
3 to 4 @ 1250 r.p
3 to 4 @ 1250 r.p
3 to 4 @ 1250 r.p
3 to 4 @ 1250 r.p
3 to 4 @ 1250 r.p
3 to 4 @ 1250 r.p
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3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p
3 to 4 @ 1000 r.p

TABLE V—(Continued)

Characteristics of North East Starting and Lighting Apparatus

Mechanical Characteristics								Approximate Electrical Characteristics								
											Master Relay			Lim.Rl	Resis. Unit	
Shown on Plate	Model	Drg. No.	Volts	Rotation	Arm. Dia. (in.)	Style Coupling	Style Terminals	Charge Rate Amp.	Torque Ft.-Lb. @ Amp.		Cuts in Pos. Amp.	Cuts Out Neg.A.	Air Gap (in.)	Air Gap (in.)	No. of Spools	Total Resis.
125	D-2	1257	12	C.C.	3¾	Oldham......	4 Post...	7	32	200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
126		1258	12	C.	3¾	Sprocket.....	4 Post...	7	32	200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
126-A							4 Lead...									
126		1259	12	C.C.	3¾	Sprocket.....	4 Post...	7	32	200	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
126-A							4 Lead...									
80-A	D-9	1264	12	C.	4	Sprocket.....	4 Lead...	6.5	35	210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
80-A	D-9	3520	12	C.C.	4	Sprocket.....	4 Lead...	7	35	210	3 to 4 @ 1000 r.p.m.	0	.030	.025	2	19ω
126	F-3	3500	24	C.	4	Sprocket.....	4 Post...	6	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
126-A							4 Lead...									
126	F-3	3500F	24	C.	4	Sprocket......	4 Post...	4	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
126-A							4 Lead...									
126		3502	24	C.	4	Sprocket......	4 Post...	6	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
126-A							4 Lead...									
123	B-4	3505	24	C.C.	4	Oldham......	5 Post...	6	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
123	B-4	3505	24	C.C.	4	Oldham......	5 Post...	6	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
125	D-3	3508	24	C.	4	Oldham......	4 Post...	6	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
124	D-8	3510	24	C.	4	Flange.......	4 Post...	6	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
	D-4	3551	16	C.C.	4	Oldham......	4 Lead...	7	44	240	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
	D-5	3552	24	C.	4	Oldham......	4 Lead...	6	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
126-A	F-5	3550	16	C.	4	Sprocket.....	4 Lead...	7	44	240	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
80-A	D-10	3546	24	C.	4	Sprocket.....	4 Lead...	6	55	200	3 to 4 @ 1250 r.p.m.	—1	.030	.025	2	28ω
841	G-1	3554	12	C.	3.990	Sprocket.....	2 Post...	7½	36	240	1 to 1½ @ 1000 r.p.m.	—1	.030	No Li	miting	Relay
841	G-1	3555	12	C.C.	3.990	Sprocket.....	2 Post...	7½	36	240	1 to 1½ @ 1000 r.p.m.	—1	.030	No Li	miting	Relay
841	G-2	3556	24	C.	3.990	Sprocket.....	2 Post...	6	55	220	1 to 1½ @ 1150 r.p.m.	—1	.030	No Li	miting	Relay
841	G-2	3557	24	C.C.	3.990	Sprocket.....	2 Post...	6	22	220	1 to 1½ @ 1150 r.p.m.	—1	.030	No Li	miting	Relay

Replacing Dodge Chain. When the driving chain on any equipment operated in this manner has worn to a point where it no longer makes proper contact with the sprockets (the chain being adjusted to the correct tension), it will be necessary to replace it. While the following instructions for "fishing" the chain through the housing apply particularly to the Dodge car, with little modifications here and there they will be found equally applicable to all similar installations.

Having removed the old chain, pass a short piece of wire through the end of the new chain, Fig. 308. Then start the chain on the lower side of the sprocket, as shown in the illustration, hooking the wire through the sprocket to keep the chain in mesh, and slowly turn the engine over by hand until the chain appears at the top of the sprocket. Then remove the wire from the sprocket, hold the end of the chain, and continue to turn the engine over until the chain is in a position to apply the master link.

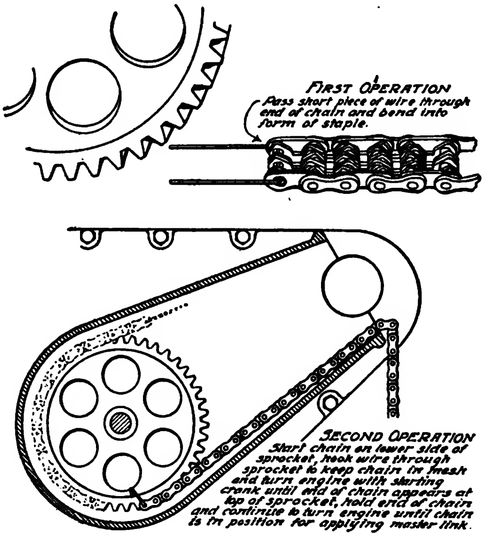
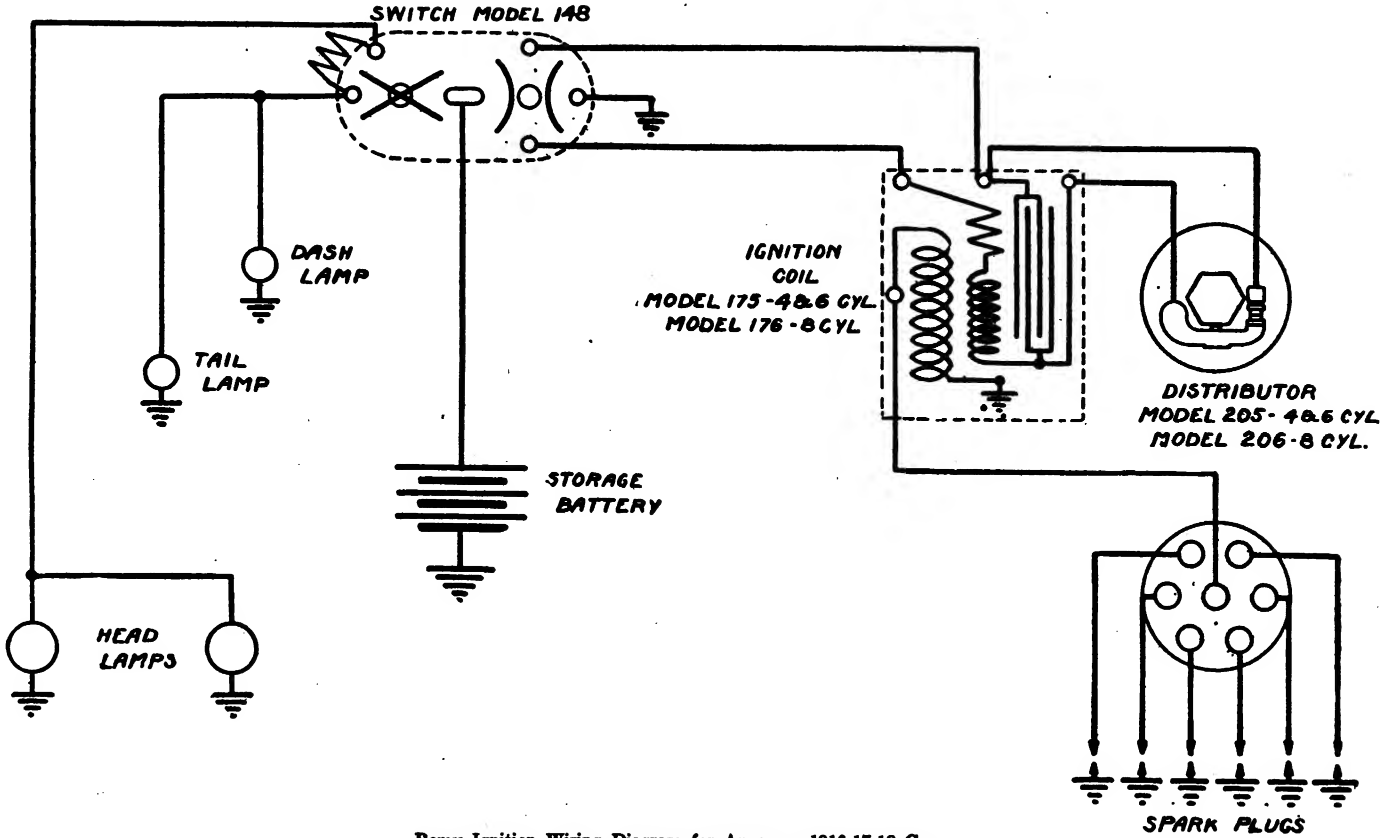


Fig. 308.—Diagram Showing Method of Inserting Chain in North East Equipment on Dodge Cars

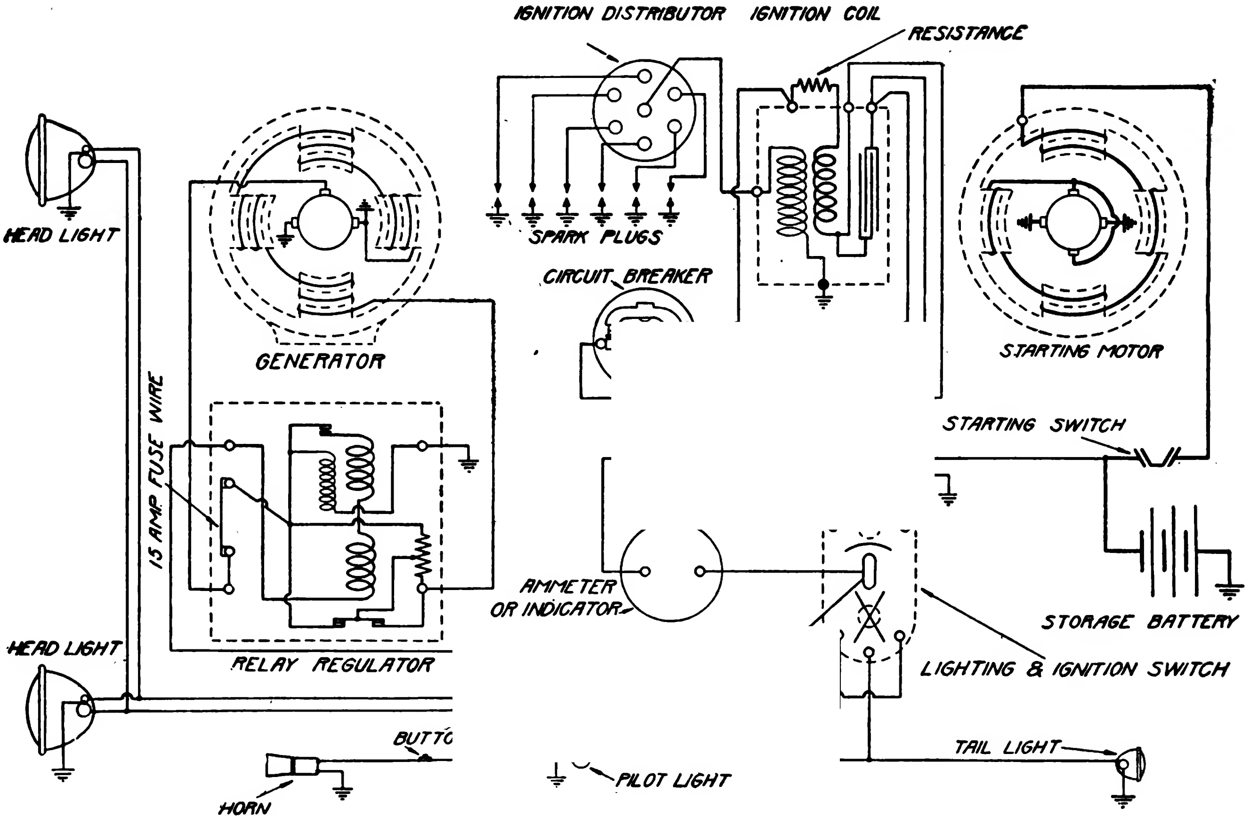
Mechanical and Electrical Characteristics. When it is desired to make bench tests of any of the North East apparatus with the aid of the outfit described in connection with the Gray & Davis tests, the data shown in Table V will be found valuable for checking purposes. The left-hand columns give the mechanical characteristics, with the aid of which the unit may be identified, while the right-hand columns give the electrical characteristics, such as the charging rate, torque in foot-pounds with given current input, cutting-in and cutting-out points of the master relay (battery cut-out), air gaps for the limitation relay, and the resistance of the units.

Remy Ignition, Starting, and Lighting Installation on Auburn 1917 Cars, Model 6-39
Courtesy of Remy Electric Company, Anderson, Indiana

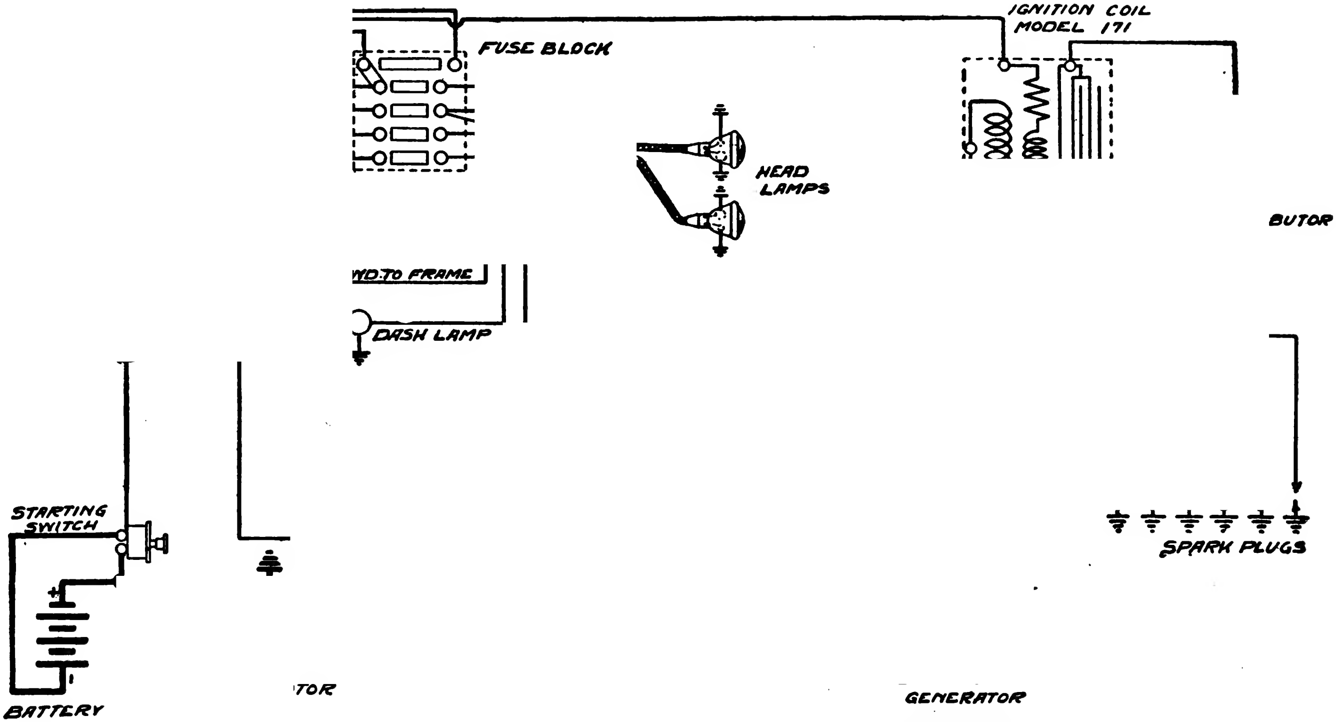
Remy Ignition, Starting, and Lighting Installation on Auburn 1916 Cars, Models 4-38, 6-38, 6-40



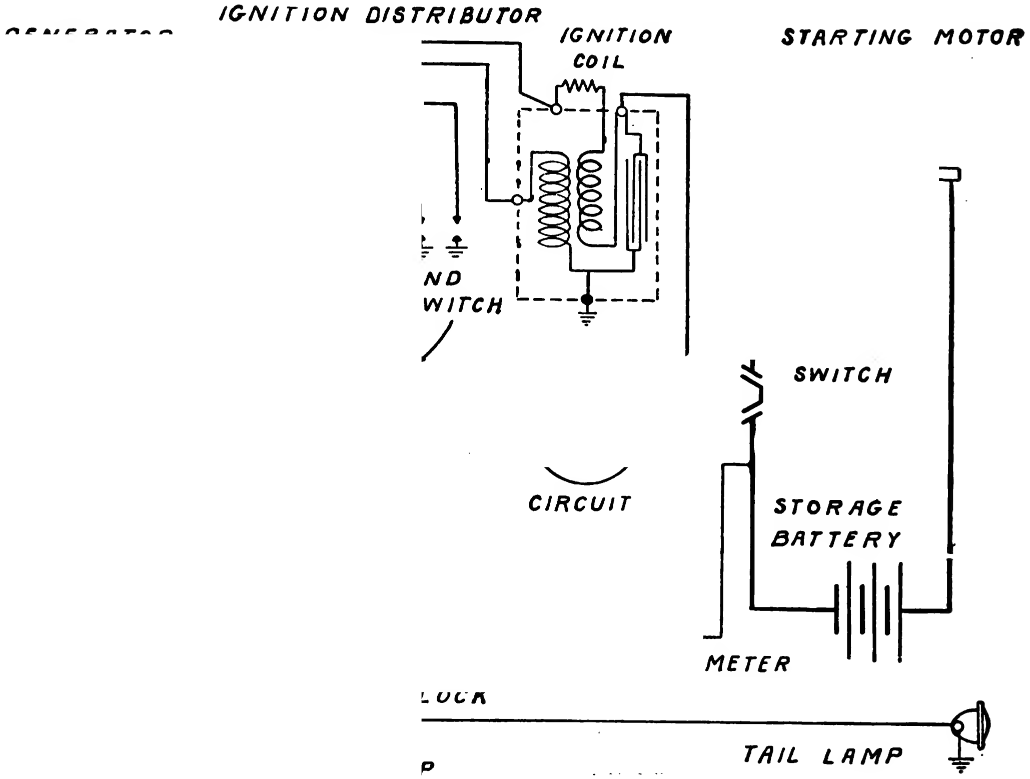
Remy Ignition Wiring Diagram for Apperson 1916-17-18 Cars



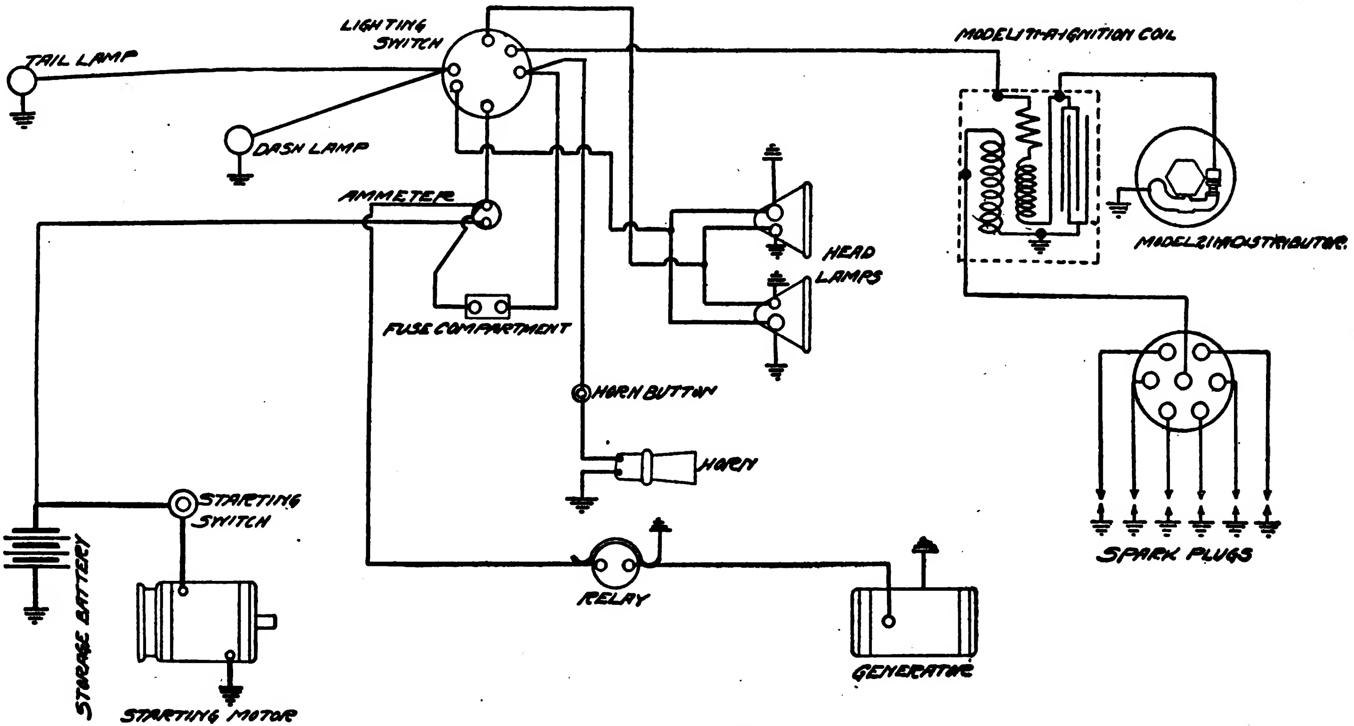
Remy Ignition, Starting, and Lighting Installation on Abbott Detroit 1917 Cars



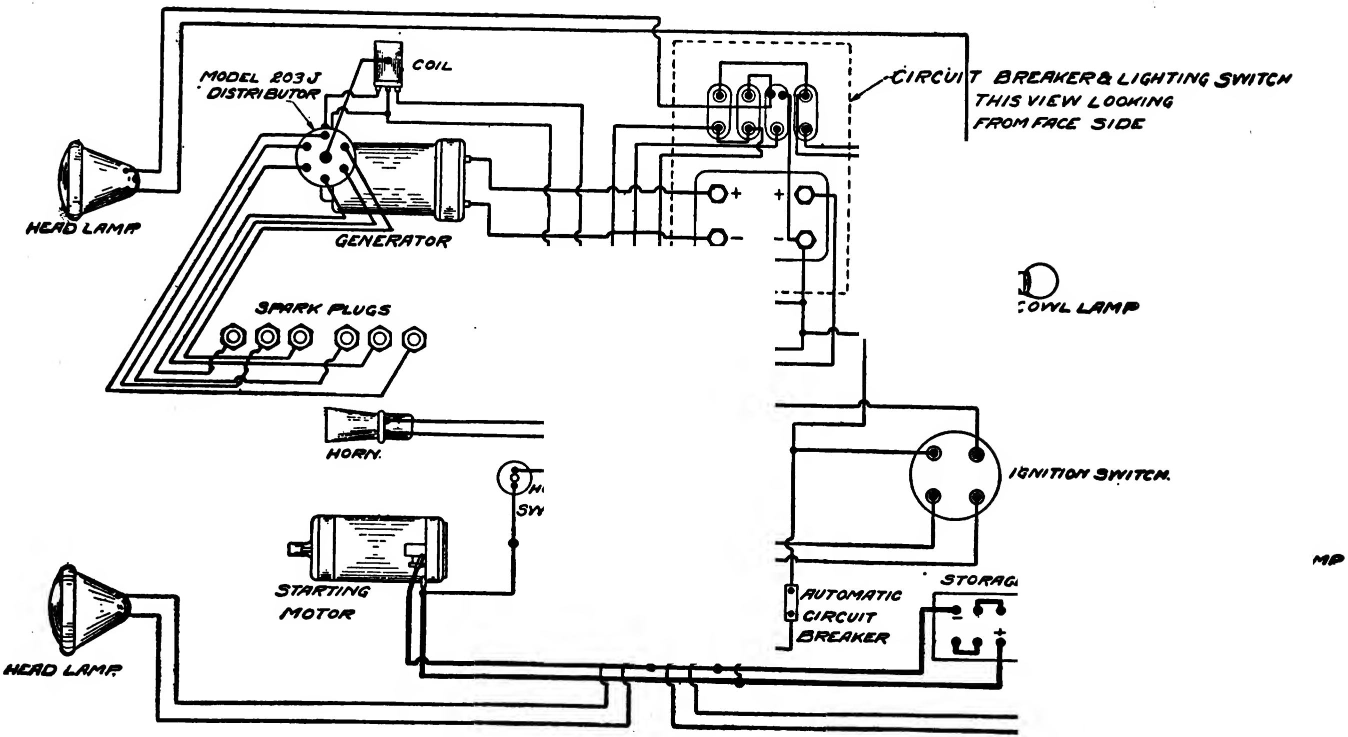
Remy Ignition and Westinghouse Starting and Lighting Installations on Chalmers 1916-17 Cars



Remy Ignition and Westinghouse Starting and Lighting Installations on Chalmers 1918 Cars



Remy Ignition and Wagner Starting and Lighting Installations on Grant 1916-17 Cars, Model K



Remy Ignition Wiring Diagram for Haynes 1916-17 Cars

REMY SYSTEM

Six-Volt; Two-Unit; Single-Wire

Generator. Of the multipolar (four-pole) shunt-wound type of generator combined with ignition timer and distributor and designed to be driven at 1½ times crankshaft speed, several models are made, of which one is shown in Fig. 309. In this case, both the regulator for the generator and the battery cut-out are mounted directly on the generator. On some of the models only the regulator is so mounted, the cut-out being placed on the dash of the car, while on others no independent regulating device is required as the third-brush type of regulation is employed (on bipolar generator).

Regulation. In accordance with the model of generator and the requirements of the engine to which it is to be fitted, either the constant-voltage method of regulation using a vibrating regulator mounted on the generator or the third-brush method is employed.

Fig. 309. Remy Ignition Generator and Distributor
Courtesy of Remy Electric Company, Anderson, Indiana

Constant-Voltage Method. The regulator for the generator is similar in principle to that described in connection with the Bijur system. It consists of an electromagnet; two sets of contact points, two of which are mounted on springs; a pivoted armature which may move to make or break the circuit; and a resistance unit. When running at too slow a speed to produce its maximum output, the generator field is supplied with current passing directly through the regulator contact points, which are held together by a spring. As soon, however, as the speed of the generator increases to a point where it tends to cause its output to exceed the predetermined maximum, the charging current which is flowing through the coil of the electromagnet energizes it so such an extent as to cause it to pull the armature down. This separates the contacts and causes the field current to pass through the resistance unit, thus decreasing the field current and, in turning, decreasing the generator output, which reduces the exciting effect on the electromagnet and causes it to release its armature, cutting the resistance out of the field circuit. The latter immediately builds up again, and the operation is repeated as long as the speed remains excessive for the generator, which is thus supplied with a pulsating current to excite its fields, and its output is held at a practically constant value.

Third-Brush Method. The third-brush method of regulation is based upon the distortion of the magnetic field of a generator at high speeds. When running at low speeds, the magnetic flux of a generator is evenly distributed along the faces of its field pole pieces, but at high speeds there is a tendency to drag it out of line in the direction of the rotation of the armature. It is then said to be distorted. The third brush, which supplies the exciting current to the field winding, is so located with relation to the main-line brush of opposite polarity that this distortion of the magnetic flux reduces the current which it supplies to the fields. This decrease in the exciting current of the field causes a corresponding decrease in the output of the generator, and as the distortion of the magnetic flux is proportional to the increase in speed, the generator output falls off rapidly the faster it is driven above a certain point, so that it is not damaged when the automobile engine is raced.

Thermostatic Switch. More of the current produced by the generator is used for lighting purposes in winter than in summer, in the proportion that the demands for house lighting vary with the change of the seasons. Added to the decreased efficiency of the storage battery in cold weather, this tends to place a greatly increased load on the generator in the winter months. If the generator, as installed, were regulated to produce sufficient current to take care of this maximum demand, it would keep the storage battery in a constant state of overcharge in summer and would be likely to ruin the plates through excessive gassing. The Remy engineers have accordingly developed a method of regulation that will automatically compensate for the difference in the demand with the changing seasons, consisting of a thermostatic switch in connection with the third-brush control; it will be found, among others, on the Reo 1917 models.

Remy Ignition and Westinghouse Starting and Lighting Installations on H A L 1917 Twelve-Cylinder Cars

Remy Ignition, Starting, and Lighting Installation on Harroun Cars, Model AA1

To gain a clear idea of the action of an electric thermostat, the heating effect of the current must be kept in mind; also that different metals have different coefficients of expansion, i.e., some will expand more than others under the influence of the same degree of heat. Electric thermostats have been in use for years as automatic fire alarms and as temperature-controlling devices in incubators and for residence heating, and within the past few years they have come into use on the automobile to control the circulation of the cooling water and the suction of the engine in accordance with variations in the temperature. The device consists of a thermal member, or blade, of two different metals riveted together at their ends. This member is held fast at one end and at the other it carries a contact point, designed to complete the circuit by touching a stationary contact. Under the influence of an increase in temperature, one of the metals expands more than the other and thus springs this member, or blade, away from the stationary contact.

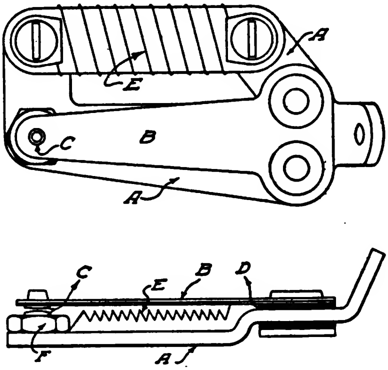


Fig. 310. Details of Remy Thermostatic Switch

Fig. 311. Wiring Diagram of Switch Connections

The details of the Remy thermostat are shown in Fig. 310. *B* is the thermo-member carrying the silver contact *C*, and is supported on a strip of steel *A*. *A* also carries the resistance unit *E*, which is a short coil of high-resistance wire wound on heavy mica insulation. *A* and *B* are riveted together at the end *D* so as to insulate them from each other. The two metals composing *B* are spring brass and nickel steel, the strip of spring brass being placed on the lower side of the blade. Sufficient tension is placed on this strip, by means of the adjusting nut *F*, to keep the points firmly in contact at temperatures below 150° F. This adjustment is made by the manufacturer and is permanent.

As shown in the wiring diagram, Fig. 311, which illustrates the relation of the thermo-switch to the third-brush method of regulation, it will be noticed that the switch is placed near the commutator of the generator, as that is the hottest part of the machine when it is in operation. It will be noticed also that when the contact points of the thermo-switch are open, as shown in the illustration, the current supplied to the field by the third brush must pass through the resistance unit of the switch, thus cutting it down. This is the position for warm-weather running, when not so much of the current is required for lighting, and when the storage battery is at its best. When the temperature of the air about the thermo-switch exceeds 150° F., the movable blade is warped upward, owing to the greater coefficient of expansion of the brass as compared with that of the nickel steel. The contact points will accordingly remain open as long as the temperature exceeds this degree. When it falls below that point, the quicker contraction of the brass pulls the blade down, and the points again make contact, cutting out the resistance and increasing the output

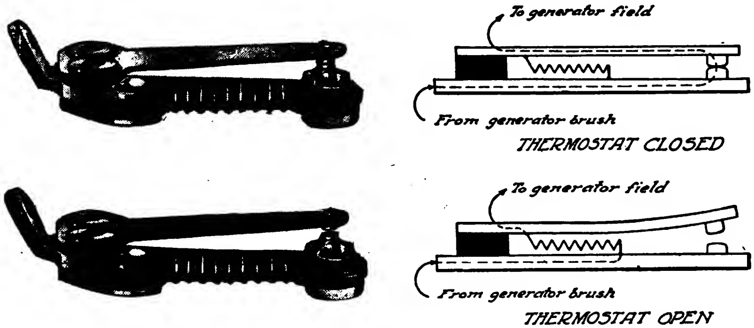


Fig. 312. Photographic Reproductions and Diagrams of Action of Thermostatic Switch When Closed and Opened

Courtesy of Remy Electric Company, Anderson, Indiana

Remy Ignition, Starting, and Lighting Installation on Interstate 1916-17 Cars

STARTING MOTOR

GENERATOR

Remy Ignition and Kissel Starting and Lighting Installations on the Kissel One Hundred Point Six, 1916 of the generator, diagrams of the thermo-switch in its closed and open positions being shown at the right, and a halftone of the switch at the left in Fig. 312, while the curves, Fig. 313, show the increase in the current output brought about by the closing of the thermo-switch points. The path taken by the current when the points are open and when they are closed is indicated by the dotted lines in the diagrams, Fig. 312. The curves show that with the thermo-switch open, the maximum current output of the generator is limited to 14 to 15 amperes, while with the switch closed it rises to 20 to 22 amperes. The switch will normally remain closed after the engine has been idle for any length of time; but in summer it will open after driving a few miles, while in winter it will probably remain closed, no matter how much the car is driven.

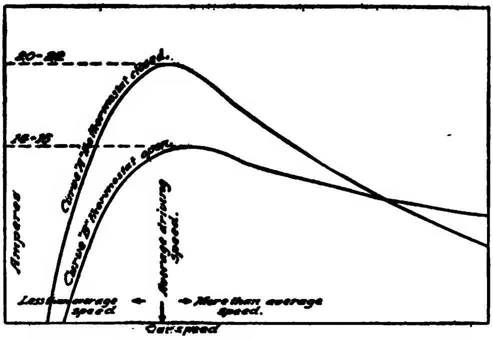


Fig. 313. Output Curves of Remy Patented Generator

Starting Motor. The motor is the 6-volt 4-pole series-wound type, illustrated in Fig. 314, mounted either with gear reduction and over-running clutch, or with automatically engaging pinion for direct engagement with flywheel gear, as described in connection with the Auto-Lite. The latter is known as the Bendix gear. The control is by independent switch.

Fig. 314. Remy Starting Motor with Outboard Type Bendix Pinion

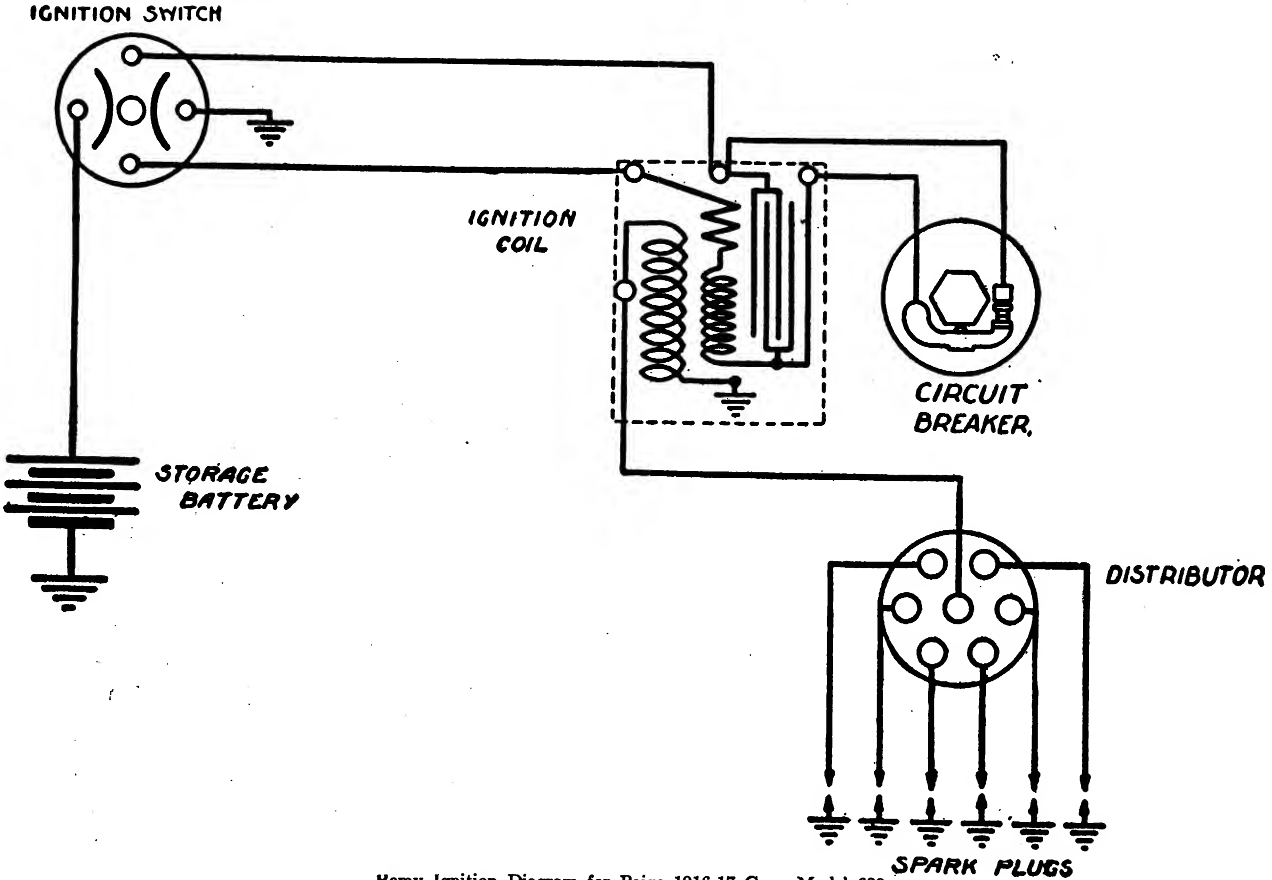
Instruments and Protective Devices. An indicator, or *telltale*, shows when the battery is charging or discharging, and also serves to indicate any discharge, in all except the starting-motor circuit, due to grounds or short-circuits. All lamp circuits are fused, and a fuse is inserted in the regulator circuit.

Remy Single-Unit

A Mechanical Combination. While termed a single-unit type, this is actually two independent units combined, *mechanically* and *not electrically*, so that it bears no resemblance to the single unit on which both field and armature windings are carried on the same pole pieces and armature core. The field frame for the two units is a single casting, Fig. 315, but the magnetic circuits of both the generator and the motor are entirely independent, and each is a separate unit. They are combined in this manner solely for convenience in mounting where space is limited. The vibrating type of voltage regulator is employed in connection with the generator, while the starting motor operates through a train of reducing gears and an over-running clutch. Apart from the combination of the two units and the method of starting drive which this entails, the system is the same in its essentials as where the units are mounted independently.

Fig. 315. Combined Field Frame of Generator and Motor for Remy Single-Unit System

Wiring Diagrams. Velie. Fig. 316 shows the installation on Velie, Model 22, and the details will be plain with further explanation. The "ratchet reversing switch", shown in the diagram, is for controlling the ignition current, and it is designed to reverse the direction of this current each time the switch is turned on in order to prevent the formation of a crater and cone on the ignition interrupter contacts, as previously described, thus keeping the points in good work-



Remy Ignition Diagram for Paige 1916-17 Cars, Model 639

Remy Ignition, Starting, and Lighting Installation on Paige Cars, Model 6-55

Fig. 316. Wiring Diagram for Remy Installation on the Velie, Model 22

ing order for a much longer period. The dash and tail lights are 3½-volt lamps, wired in series, so that the failure of one puts the other out, thus giving an indication at the dash of the failure of the tail light.

Oakland. The Remy installation on Oakland Model 32 is shown in Fig. 317. The chief distinction between this and the previous diagram is the employment of a single 10-ampere fuse on the lighting circuits instead of independent fuses on each circuit. "Breaker box" refers to the ignition-circuit contact-breaker, or interrupter, as it is variously termed. The starting motor in this case is fitted with the Bendix drive.

Reo. On the Reo installation, Fig. 318, the starting motor is mounted on the transmission housing and drives to a shaft of the latter through a worm gear. In this case the starting switch is mounted directly on the starting motor, and an ammeter is supplied on the charging circuit instead of a telltale, or indicator.

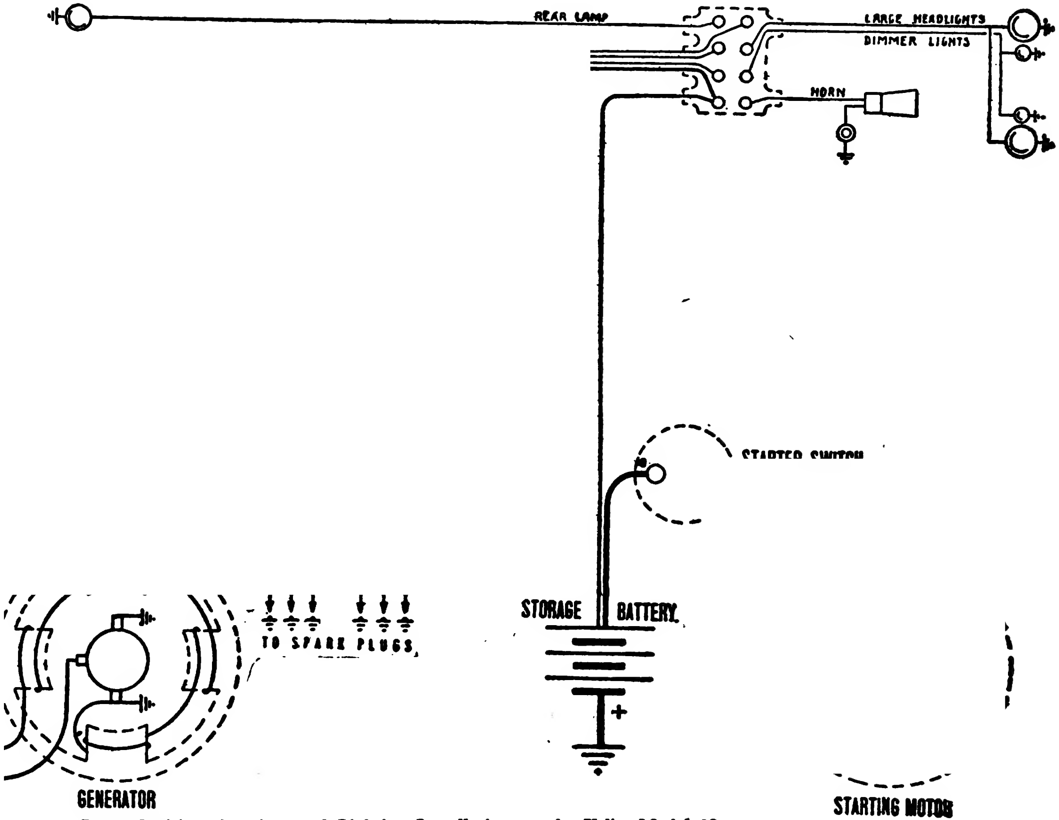
National. A typical installation of the single unit, or so-called double-deck unit, is shown in Fig. 319. This is on the National six-cylinder model and is a two-wire system. It is not interconnected with the ignition system, so there are no ground connections, and no fuses are employed.

Instructions. These instructions cover the systems which include the ignition. For instructions applying to the double-wire system on cars having an entirely independent ignition system, like the National, see instructions under Auto-Lite, Delco, Gray & Davis, and others, for failure of generator or motor, short-circuits, and the like.

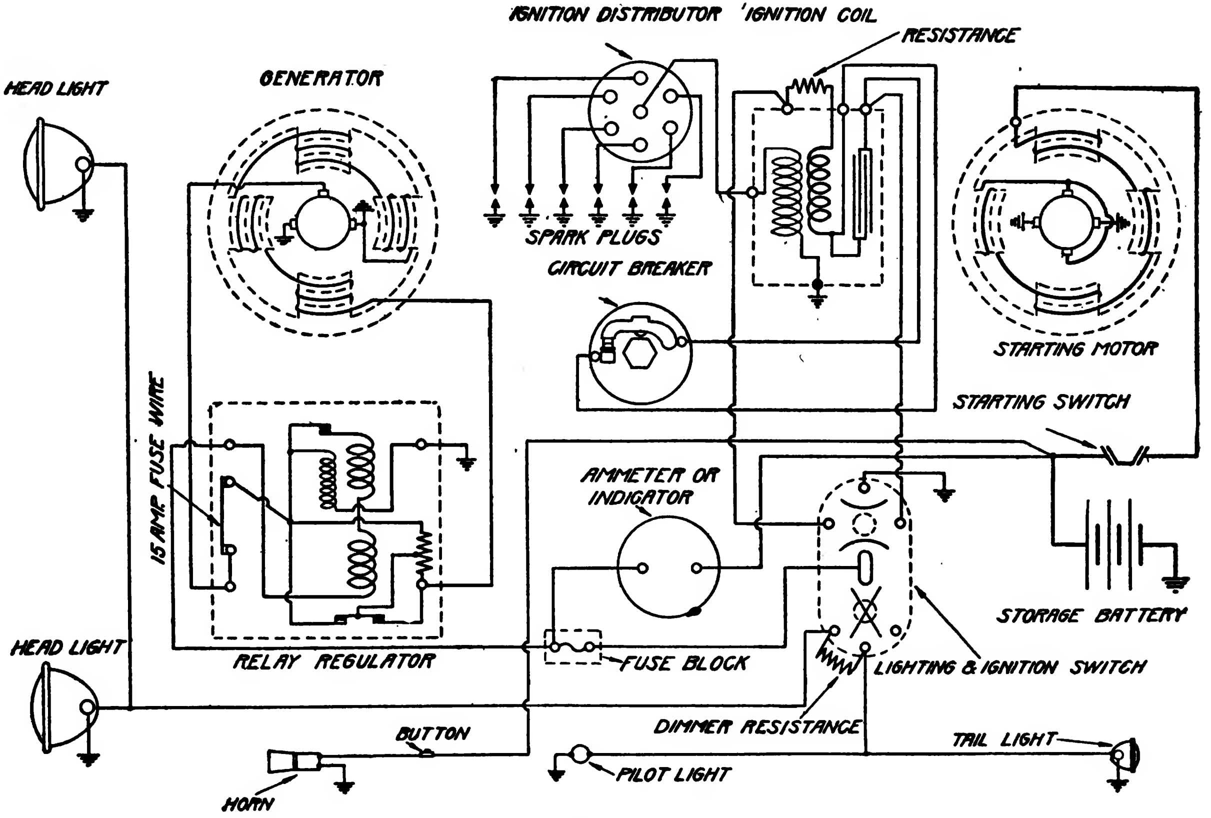
Battery Discharge. In systems of this type, discharge of the battery may be due to failure to open the ignition switch after stopping the car. The amount of current consumed is small but in time it will run the battery down. The indicator or the ammeter, according to which is fitted, will show a discharge. An entire failure of the current may indicate: a loose connection at battery terminals, at battery side of starting switch in connection with a blown main fuse (Oakland), or a loose battery ground connection; a loose connection at motor side of starting switch or at starting motor, or a broken wire between the switches. (See previous instructions on other makes for testing with lamp set for broken or grounded circuits.)

IGNITION DISTRIBUTOR IGNITION COIL

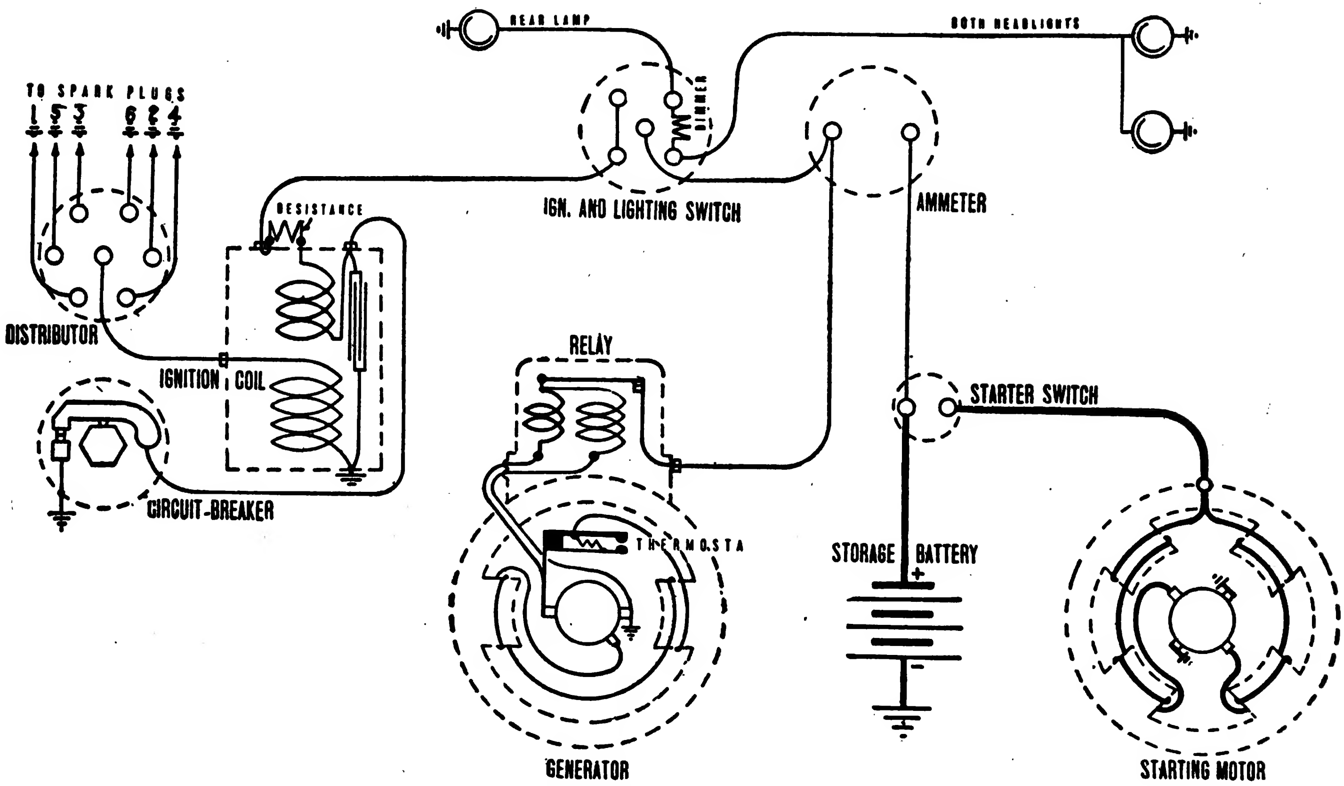
Remy Ignition, Starting, and Lighting Installation on Velie 1916 Cars, Model 22



Remy Ignition, Starting, and Lighting Installation on the Velie, Model 28



Remy Ignition, Starting, and Lighting Installation on Oakland Model 32, and McLaughlin Cars



Remy Ignition, Starting, and Lighting Installation on Oakland 1917, Model 34-B

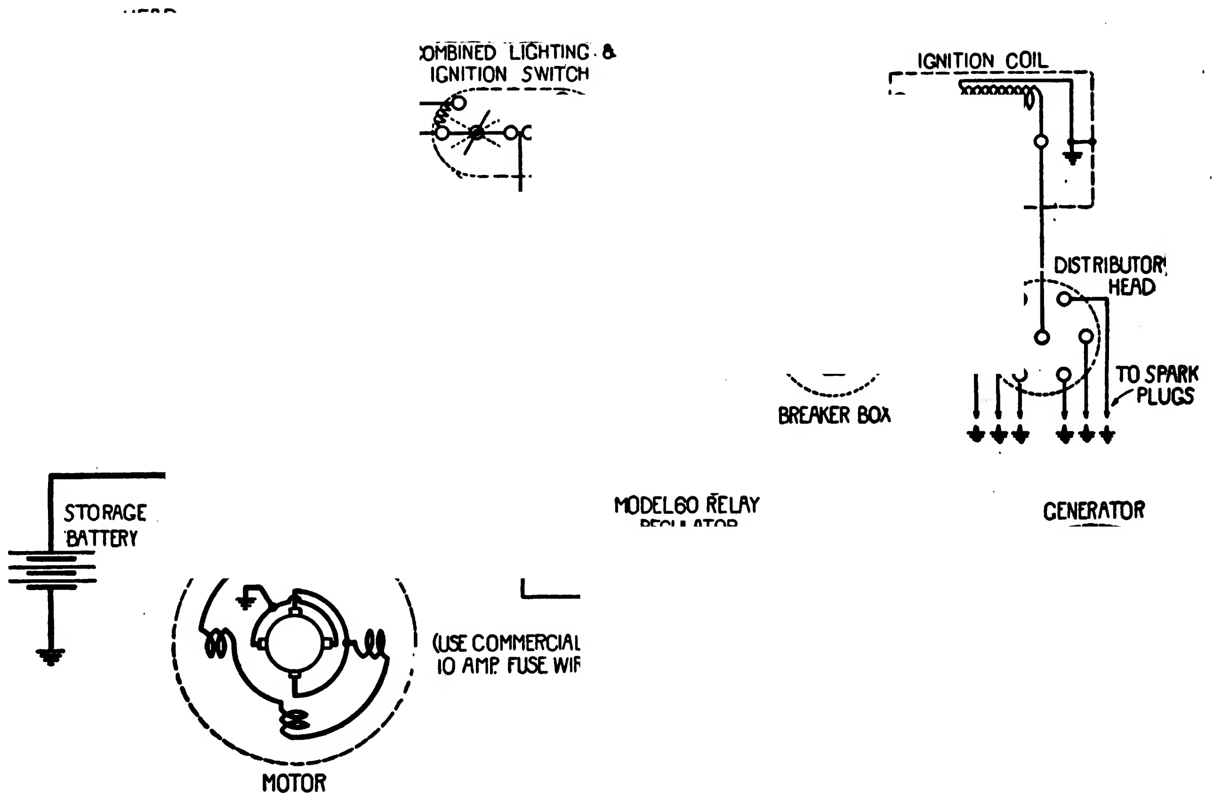


Fig. 317. Wiring Diagram for Remy Installation on the Oakland, Model 32

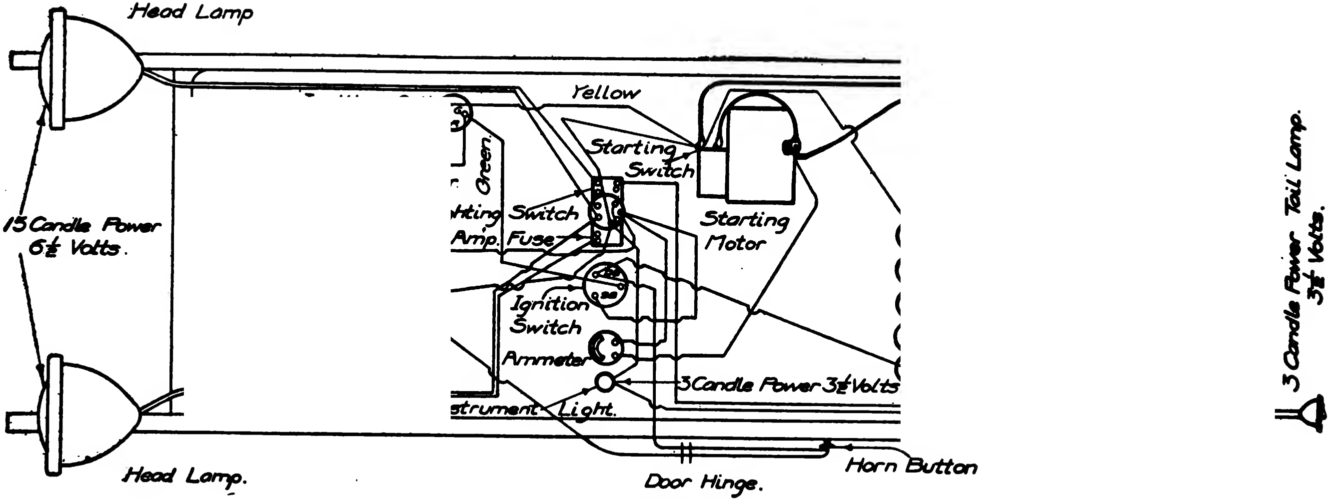
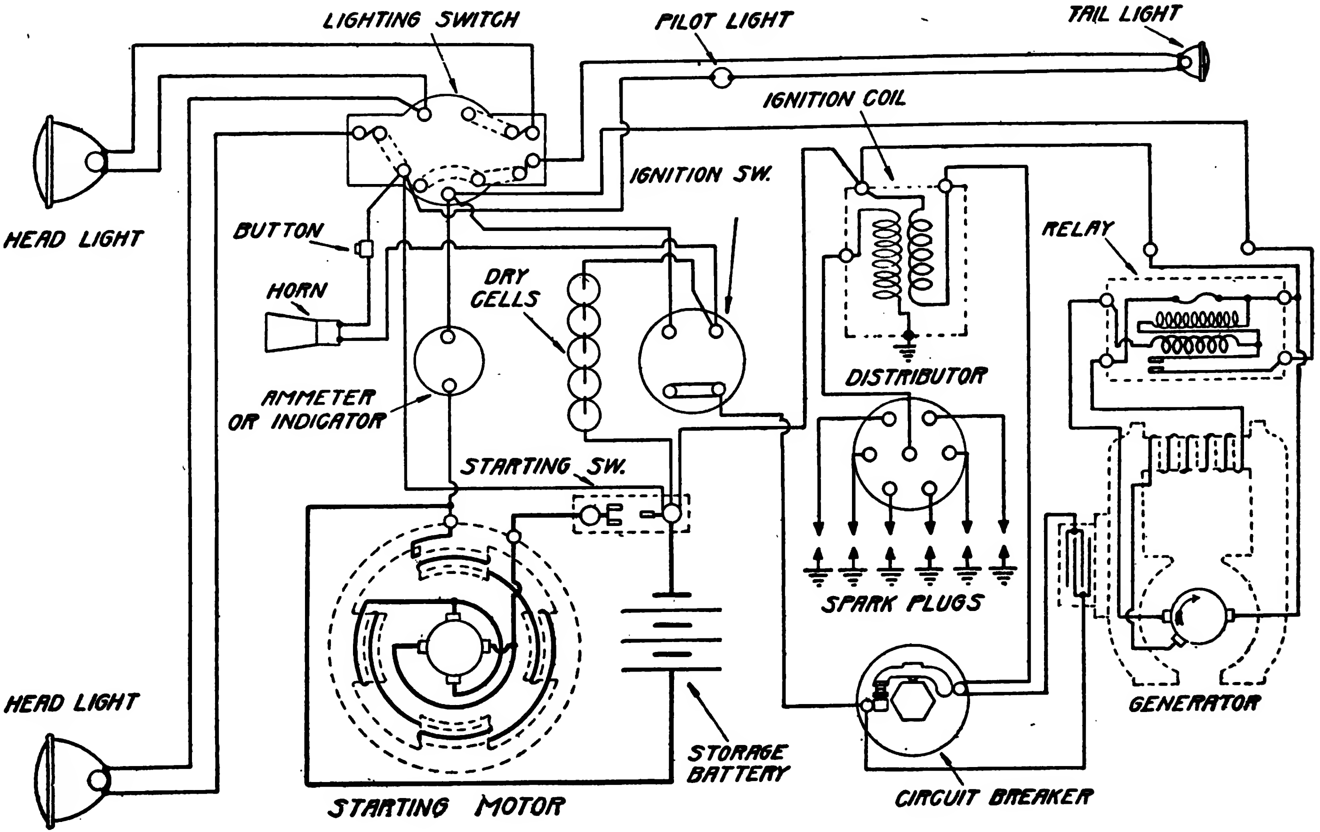
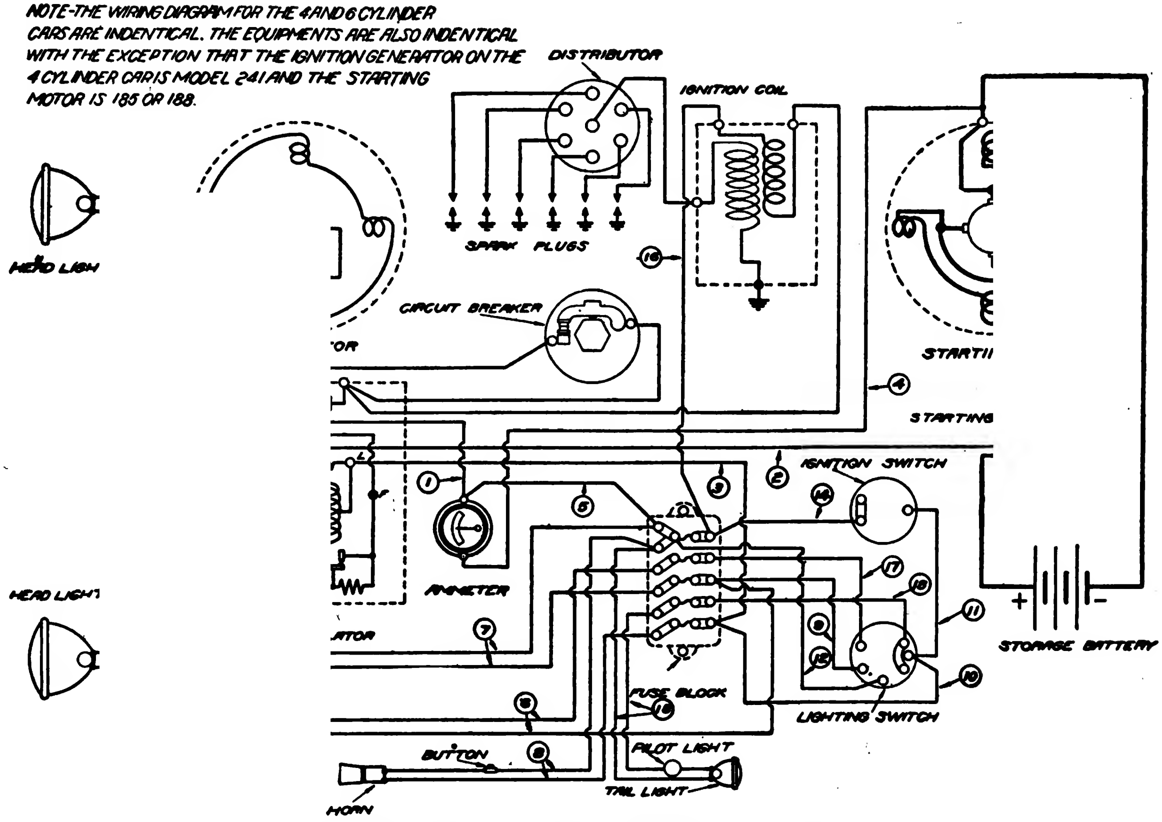


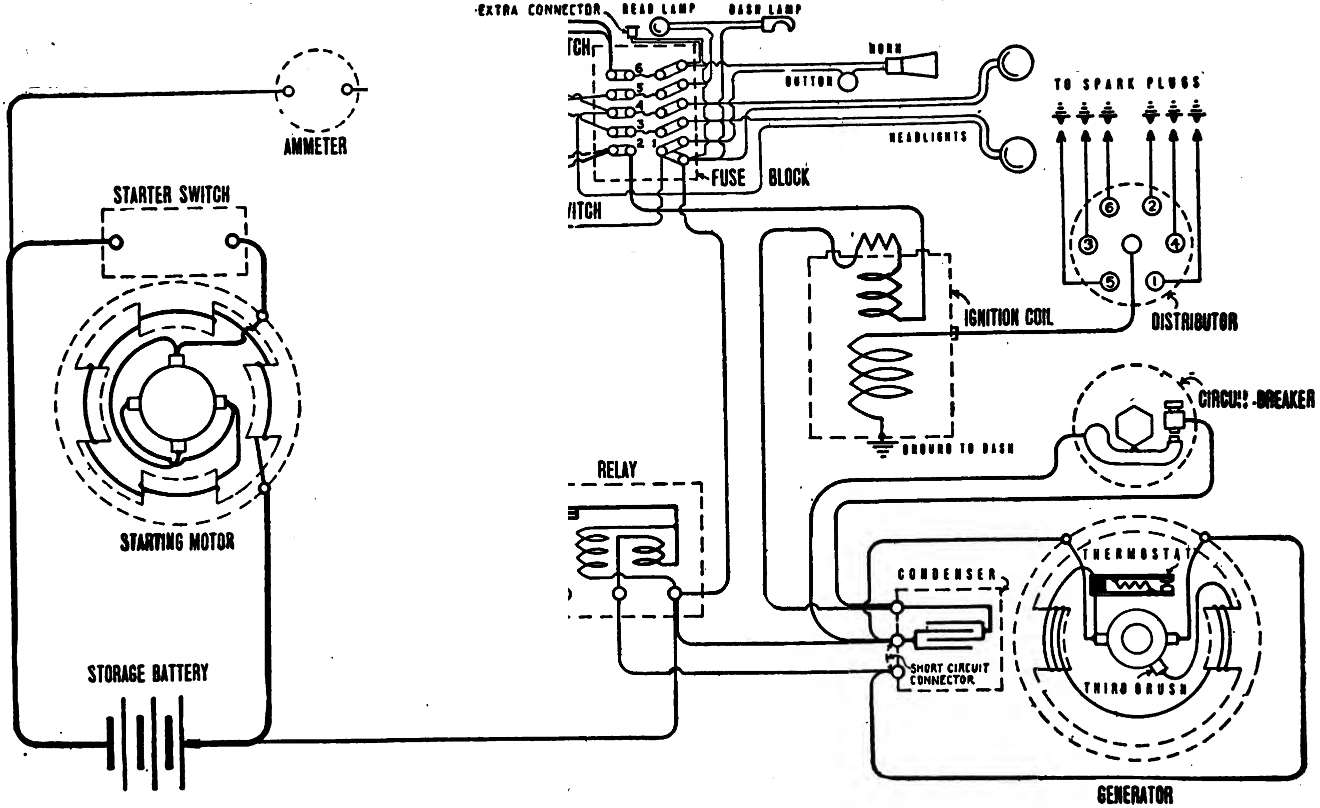
Fig. 318. Wiring Diagram for Remy Installation on "Reo the Fifth"



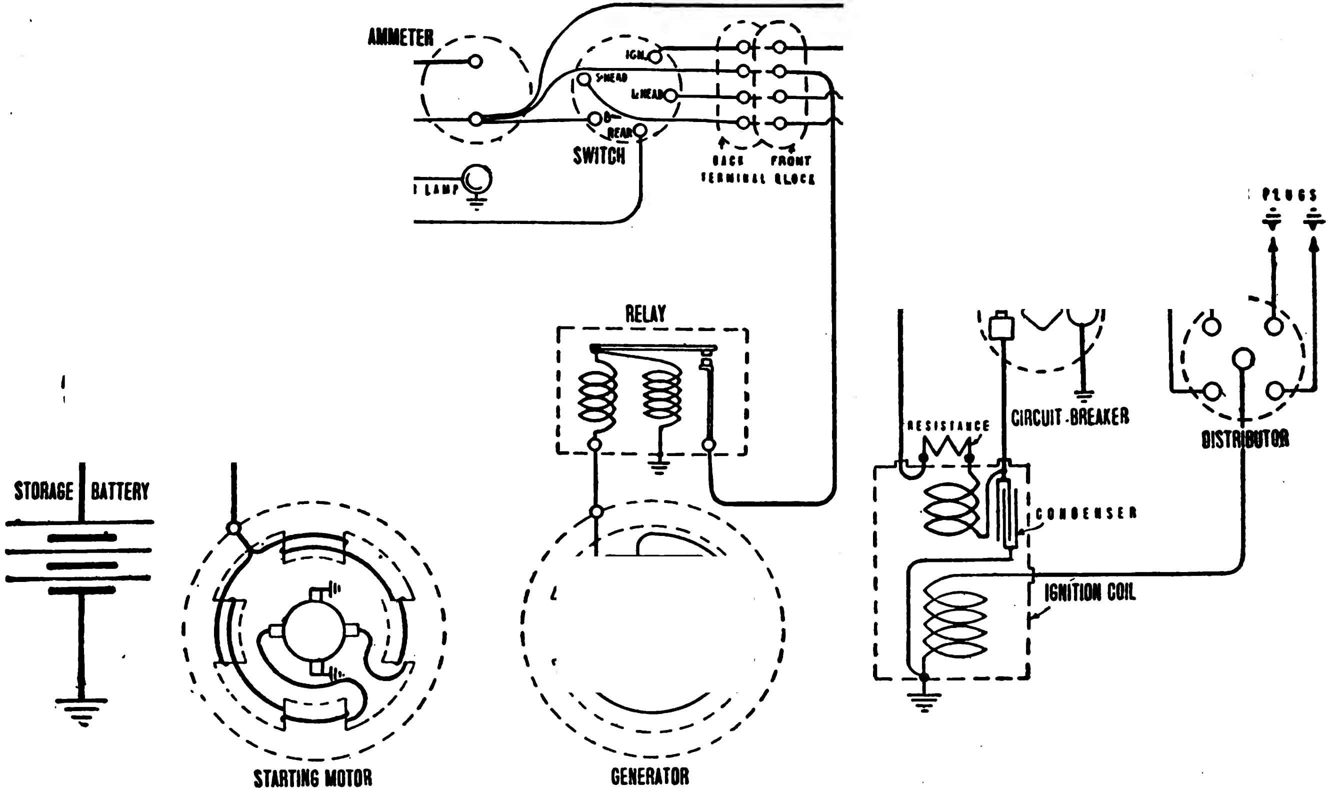
Remy Ignition, Starting, and Lighting Installation on Reo 1914-15 Cars


NOTE-THE WIRING DIAGRAM FOR THE 4 AND 6 CYLINDER CARS ARE INDENTICAL. THE EQUIPMENTS ARE ALSO INDENTICAL WITH THE EXCEPTION THAT THE IGNITION GENERATOR ON THE 4 CYLINDER CAR IS MODEL 241 AND THE STARTING MOTOR IS 185 OR 188.

Remy Ignition, Starting, and Lighting Installation on Reo 1916 Cars



Remy Ignition, Starting, and Lighting Installation on Reo Four- and Six-Cylinder 1917 Cars



Remy Ignition, Starting, and Lighting Installation on the Scripps-Booth, Model G

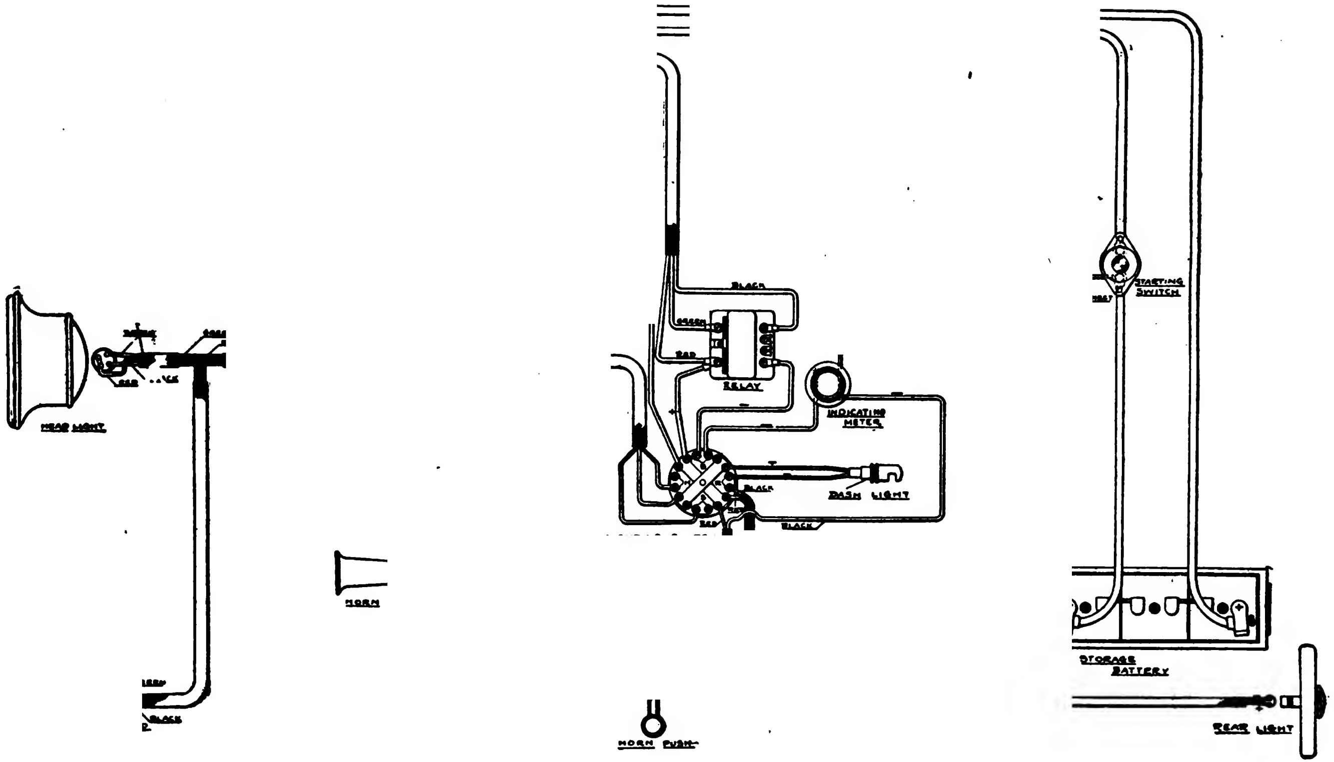


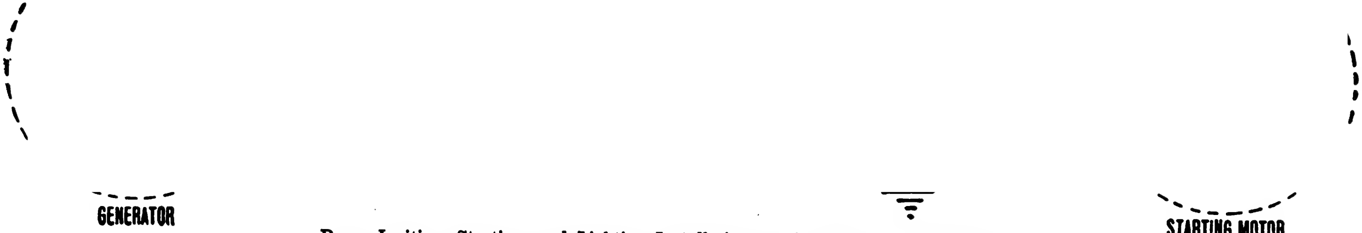
Fig. 319. Wiring Diagram for Remy Double-Deck Unit on the National Six

Failure of Lighting, Ignition, Starting. When the lights and ignition fail but the starting motor operates, it indicates a short or open circuit between the starting switch and the main fuse (Oakland). This fuse should first be examined and, if blown, a search should be made for the ground or short-circuit causing it, before putting in a new fuse. The fault will be in the wiring between the switch, lights, and ignition distributor. See that all connections, including those on fuse block, are tight. When the lights fail but the ignition and starting motor operate, the trouble will be found either in the circuits between the lighting switch and lamps; in the lamps themselves, as a burned-out bulb causes a short-circuit; or from loose connections in these circuits. Failure of the ignition, with the remainder of the system operating, may be traced to loose connections at the ignition switch, coil, or distributor; poor grounding of the ignition switch on the speedometer support screw; or to open or short-circuits between the ignition switch and the distributor. Further detail instructions on ignition are given in Ignition, Part II.

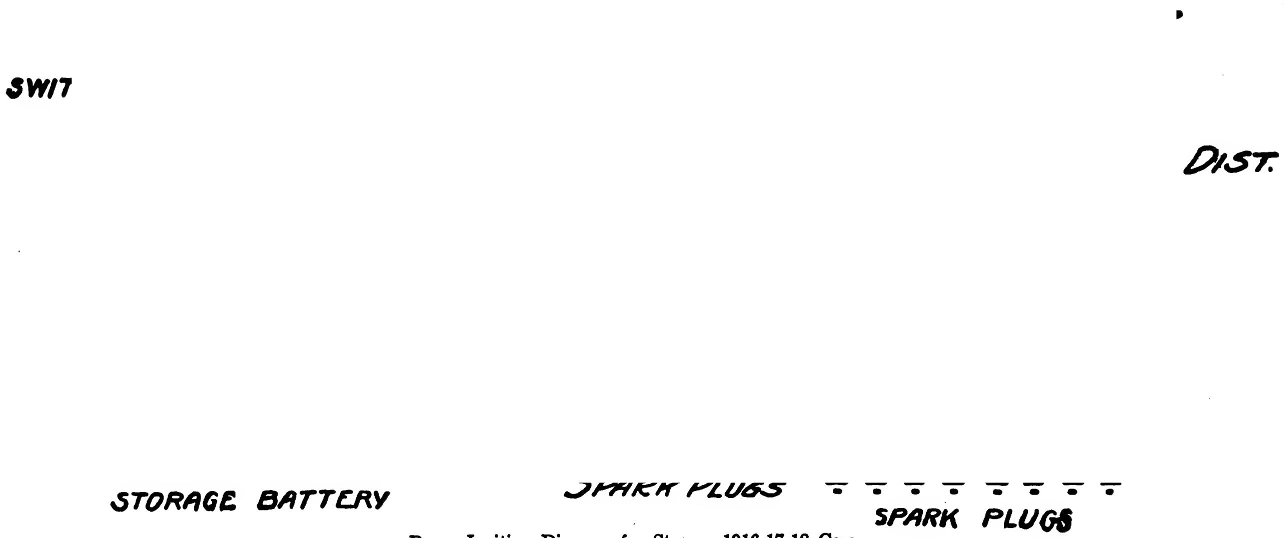
Dim Lights. When all the lights burn dimly, the most probable cause is the battery, but if a test shows this to be properly charged, a ground between the battery and the starting switch or between the latter and the generator may be responsible for leakage. Other causes are the use of higher candle-power lamps than those specified, the use of low efficiency carbon-filament bulbs, or failure of the generator to charge properly.

Examine generator-field fuse and if blown, look for short-circuits before replacing, as previously instructed. A simple test of the generator may be made by switching on all the lights with the engine standing. Start the engine and run at a speed equivalent to 15 miles per hour or over. If the lights then brighten perceptibly, the generator is operating properly. This test must be made in the garage or preferably at night, as the difference would not be sufficiently noticeable in daylight.

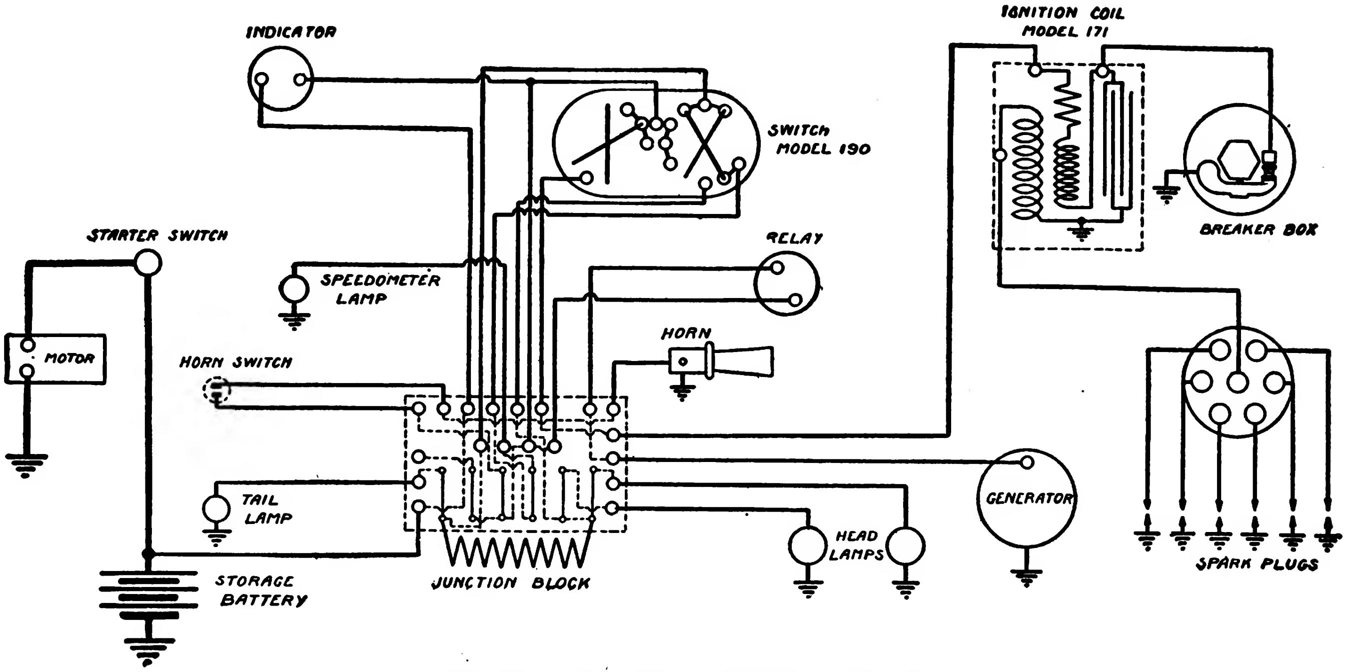
If the generator fuse is intact, examine the regulator relay contacts. If the points are stuck together, open by releasing the relay blade with the finger. Clean and true up points as previously instructed and clean out all dust or dirt from relay before replacing cover. Particles of dirt lodged between the points will prevent the generator from charging properly.



Remy Ignition, Starting, and Lighting Installation on the Stearns, Model SKL 4



Remy Ignition Diagram for Stearns 1916-17-18 Cars



Remy Ignition Wiring Diagram for Studebaker 1916-17 Cars

Remy Ignition, Starting, and Lighting Installation on Stutz 1916-17 Cars

The failure, flickering, or dim burning of any single lamp will be due to a burned-out bulb, to loose or frayed connections at lamp or switch, to a bulb loose in its socket, or to an intermittent ground or short-circuit in the wiring of that particular lamp, or to the frame of the lamp nor being grounded properly. Where dash and tail lamps are in series, examine both bulbs and replace the one that has burned out. Test with two dry cells connected in series.

Ammeter. When the indicator, or ammeter, does not register a charge with the engine running with all the lights out, stop the engine and switch on the lights. If the instrument gives no discharge reading, it is faulty. If it shows a discharge, the trouble is in the generator or connections. In case the ammeter registers a discharge with all the lights off, ignition switch open, and engine idle, examine relay contacts to see if they remain closed. If not, disconnect the battery. This should cause the ammeter hand to return to zero; if it does not, the instrument is out of adjustment. With the ammeter, or indicator, working properly, and the relay contacts in good condition, a discharge then indicates a ground or short-circuit. When examining the relay for trouble, do not change the adjustment of the relay blade.

SIMMS-HUFF SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. The dynamotor is of the multipolar type having six poles, as illustrated in Fig. 320, which shows the field frame, coils, and poles. Fig. 322 illustrates the assembled brush rigging, while Fig. 321 shows the complete unit with the commutator housing plates removed.

Regulation. Regulation is by reversed series field, in connection with a combination cut-out and regulator. The regulator is of the constant-potential type and is combined with the battery cut-out. It is connected in circuit with the shunt field of the generator, and the vibrating contacts of the regulator cut extra resistance into this circuit when the speed exceeds the normal generating rate. There is also a differential compound winding of the fields, the two halves of which oppose each other at high speeds.

Instruments. An ammeter is supplied, showing *charge* and *discharge.*

Dynamotor Connections. The dynamotor has two connections, one at the bottom of the forward end plate, marked DYN+, and the other on top of the field yoke designated as FILED. As the system is a single-wire type, the opposite sides of both circuits are grounded within the machine itself. The terminals on the cut-out are marked BAT+, DYN+, and DYN−, BAT−, and FLD.

Fig. 320. Field Frame, Poles, and Windings for Simms-Huff Dynamotor

Fig. 321. Brush Rigging for Simms-Huff Dynamotor

Fig. 322. Simms-Huff Dynamotor with Commutator Housing Plates Removed
Courtesy of Simms Magneto Company, East Orange, New Jersey

BAT+ connects through a 12-gage wire to the negative side of the ammeter and thence to a terminal on the starting switch. This connects it permanently to +R of the battery through the ammeter. This wire supplies the current to the distributing panel, from which current is supplied to the lamps and horn. DYN+ connects through a similar wire to the plus terminal of the dynamo, while DYN— and BAT— connect with the —L terminal of the storage battery through a wire of the same size.

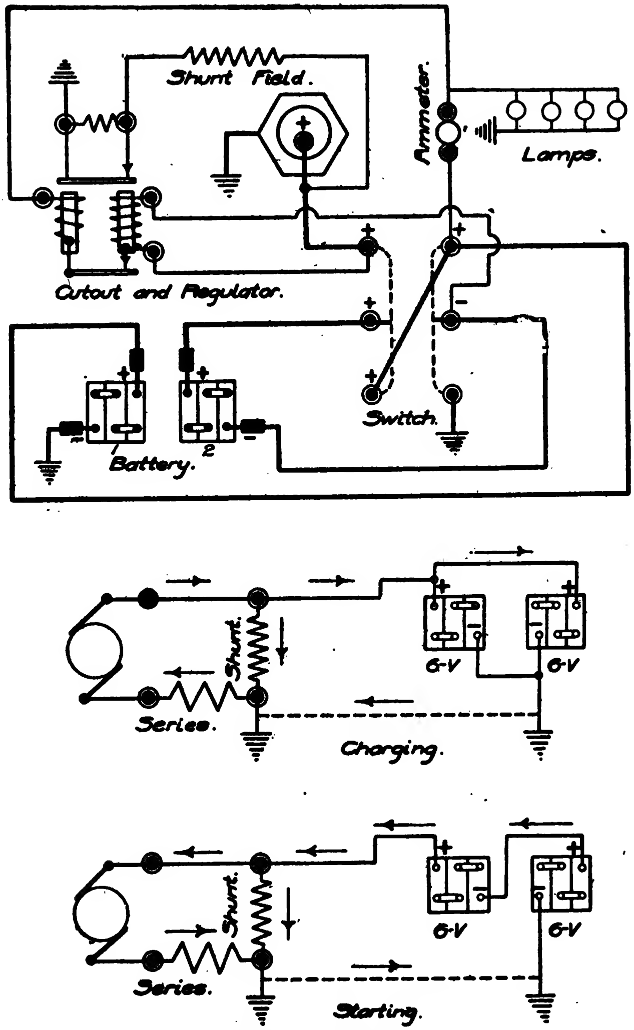


Fig. 323. Wiring Diagram for Simms-Huff Starting and Lighting Systems

Change of Voltage. The system is known as 6—12-volt type, signifying that the current is generated at 6 volts, but is employed for starting at 12 volts. There are accordingly 6 cells in the storage battery, and the latter is charged by placing the two halves of it, consisting of two 3-cell units, in parallel. This is indicated in the upper diagram, Fig. 323, also in the middle diagram, which shows the connections for charging. In the lower diagram of the figure are shown the starting connections, the switch being connected to throw the 6 cells of the battery in series, so that the unit receives current at

Fig. 324a. Complete Wiring Diagram for 1916-17 Maxwell Cars (see Fig. 324b)
Courtesy of Simms Magneto Company, East Orange, New Jersey

12 volts for starting, thus doubling its power. Six-volt lamps are employed and are supplied with current from the left-hand section of the battery, marked *1*, as shown in the upper part of the diagram.

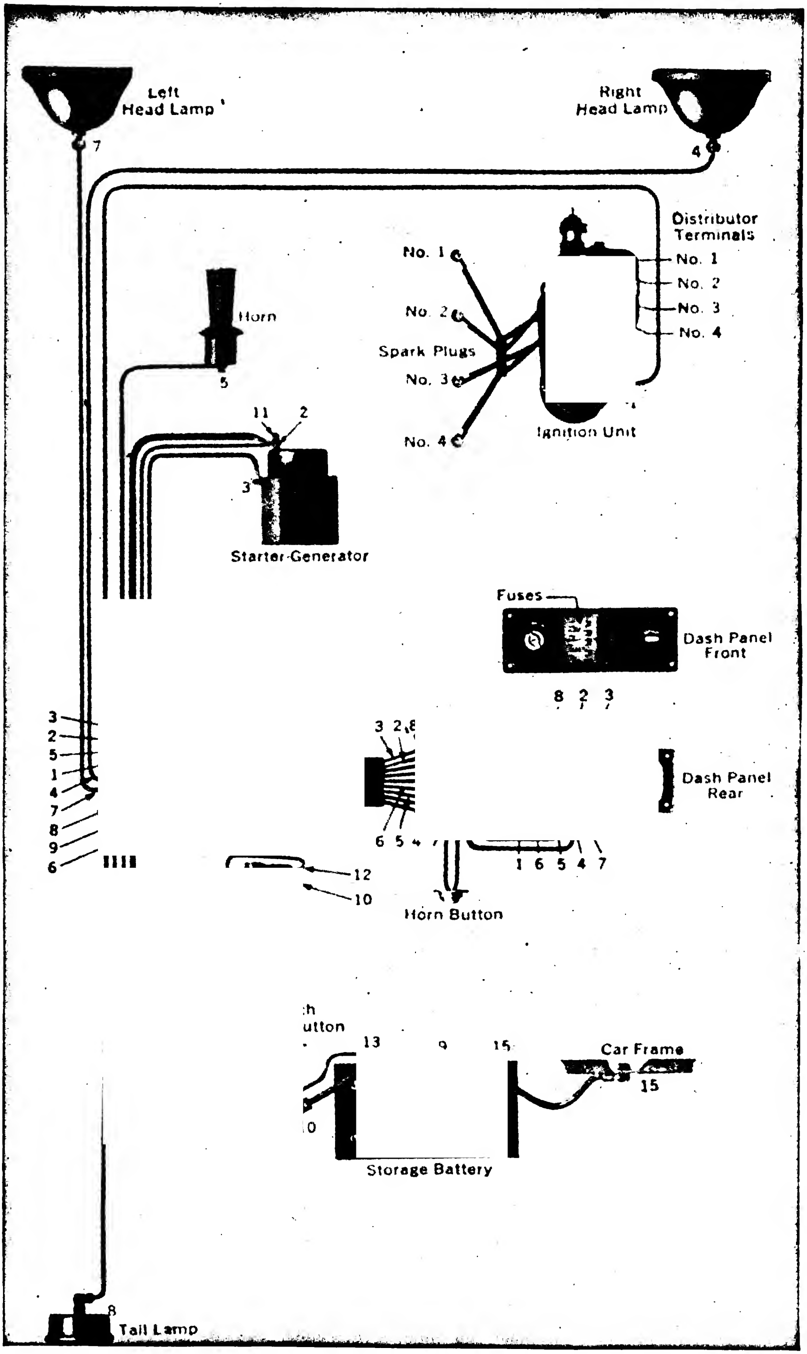
Fig. 324b. Complete Wiring Diagram for 1916-17 Maxwell Cars, Showing Details of Dash Panel and Batteries
Courtesy of Simms Magneto Company, East Orange, New Jersey

Starting Switch. This is mounted on the left side of the gearbox housing (Maxwell) and is so arranged as to connect the entire battery in series for starting, thus giving current at 12 volts for this purpose. The same movement of the starting switch also puts the battery in circuit with the ignition system so that, as soon as the engine starts and the switch is released, it automatically disconnects the battery from the ignition, and the engine then runs on the magneto (dual ignition system).

Wiring Diagram. Fig. 324*a* and Fig. 324*b* show the wiring diagram complete of the ignition, starting, and lighting systems as installed on the 1916 and 1917 Maxwell cars. The heavy lines indicate the starting-system connections, while the light lines are the wires leading from the generator to the battery (through the regulator and cut-out), and the various connections for the ignition and the lamps. They show very plainly, upon tracing them out, the relation of the regulator and cut-out to the generator and the battery, as well as the method of dividing the six cells of the battery into two units for lighting service, and the coupling of all the cells in series for starting. It will be noted also that the storage battery is not utilized for ignition, as the starting switch closes the circuit of a dry battery of four cells for ignition when starting the engine. As the starting switch automatically opens this circuit when released, there is no danger of this battery being inadvertently left in circuit.

At the upper left-hand corner of the diagram, complete details of the ignition circuit and of the magneto itself are shown. The magneto (Simms) is of the true high-tension type, having primary and secondary windings on the armature core, as well as a condenser incorporated in it. As this sketch shows not only the relation of high-tension type of magneto to the plugs but also that of the essential parts of the magneto, as well as the relation of the ignition system to the starting and lighting systems through the combination starting and ignition switch, it will repay close study. The number of wires makes it appear as if this were a two-wire system, but upon noting the ground connections at the various terminals it will be evident that it is not.

Instructions. The Simms-Huff system as above described is standard equipment on the Maxwell cars. The combination cut-out and regulator is mounted on the rear of the dash panel carrying the ammeter and switch. It consists of two distinct devices, the cut-out serving the usual purpose of protecting the battery when the generator voltage drops, and the regulator limiting the current output of the dynamo as the engine speed increases. In connection



Simms-Huff Ignition, Starting, and Lighting Installation on Maxwell 1918 Cars
Courtesy of Maxwell Motor Company, Detroit, Michigan

Wiring Diagram for Simms-Huff Starting and Lighting Installation on Maxwell 1918 Cars
Courtesy of Maxwell Motor Company, Detroit, Michigan

with it a special regulator switch is provided. This is located on the right side of the dash panel and has two positions, HIGH and LOW, the latter inserting additional resistance in the field circuit of the dynamo to further limit its output when the car is driven steadily at high speed on long runs. This switch is kept in the HIGH position for all ordinary driving and only shifted to LOW as above mentioned.

Failure of Cut-Out or of Regulator. Should the ammeter pointer go to the limit of its travel on the *discharge* side, this indicates that the cut-out contact points have failed to release on the slowing down of the generator. The latter also will continue to run as a motor after the engine is stopped. Disconnect the two wires from the terminals on the generator and wrap them with friction tape to prevent their coming in contact with any metal parts of the car. Clean and true up contact points as outlined in previous instructions. An unusually high reading on the *charge* side of the ammeter will indicate a failure of the regulator to work. If an inspection shows no sign of broken or crossed wires, loose connections, or other obvious trouble, the manufacturers recommend that the unit be sent to them. In the case of the owner, it is recommended that no attempt be made to correct faults in the cut-out or in the regulator, but that it be referred to the maker of the device or to the nearest service station.

Generator Tests. To determine whether a short-circuit or a ground exists in the brush holder, pull up all the brushes and with the aid of the lamp-test set, test by applying one end to the frame and the other to the main terminal post. The lamp will light if there is a short-circuit or a ground between the brush holder and the frame. A similar test may be made for the armature by pulling up all the brushes (or heavy paper may be inserted between them and the commutator) and placing one point on the commutator and the other on the shaft. The lighting of the lamp will indicate that the armature is grounded. In all tests of this nature where the lamp does not light at the first contact, it should not be taken for granted at once that there is no fault. Touch various parts of both members on clean bright metal. See that the points of the test set are clean, that the lamp filament has not been broken, and that the lamp itself has not become unscrewed sufficiently to break the circuit between it and the socket. A good rule is always to test the lamp itself first; sometimes the connecting plug of the set is not properly screwed into the socket.

While the above test for the armature, if properly carried out, will show whether the latter is grounded or not, it will not give any indication of an internal short-circuit in the armature itself. To determine this, connect the shunt fields and run the unit idle as a motor, with the portable ammeter in the circuit, using the 30-ampere shunt. While running without any load the motor should not consume more than 7 amperes at 6 volts, i.e., using half the battery. Tests for grounds in the shunt field may be made with the lamp-test set, but to determine whether there is a short-circuit in the field, it is necessary to measure the resistance of its windings. If there is neither a short-circuit nor a ground in the field, the resistance of the windings should calculate approximately 6½ ohms on units with serial numbers up to 27,000, and approximately 4.8 ohms on starters above this serial number.

The Simms-Huff is one of the very few, if not the only unit, that is belt-driven as a generator. Its normal output is 10 to 15 amperes; so when the dash ammeter shows any falling off in this rate, with the engine running at the proper speed to give the maximum charging current, the belt drive of the generator should be inspected. If the ammeter reading falls off as the engine speed increases, it is a certain indication that the belt is slipping and that the generator itself is not being driven fast enough. Adjust the tension of the belt and test again. If this does not increase the output to normal, inspect the commutator and brushes, brush connections and springs, etc. See that the brushes have not worn down too far, and if necessary, sand-in. Failing improvement from any of these expedients, inspect the regulator. This should not be adjusted to give more current until every other possible cause has been eliminated; and before making any change in the adjustment of the contacts, see if cleaning and truing them up will not remedy the trouble. If necessary to adjust, do so very carefully, as increasing the current output by this means will also increase the voltage, and if the voltage exceeds the normal by any substantial percentage, all the lamps will be burned out at once. Trouble in the electrical unit itself will be most likely to appear in the brush holder.

Whenever it is necessary to remove the front end plate over the commutator to inspect the commutator or the brushes, be sure that this plate *is put back the same way,* and not accidentally turned round a sixth of a revolution, which would cause the motor to run backward. There is a slot in the front end of this plate to permit the brush holder to be moved backward or forward so as to give the best brush setting as a generator and as a motor. On most of the Simms-Huff units, a chisel mark will be found on each side of the fiber insulator under the main terminal post, indicating the factory brush setting. Checking this brush setting should be one of the further tests undertaken before resorting to adjustment of the regulator. To do this, connect the portable ammeter in the charging circuit (30-ampere shunt) or, if one of these instruments is not available, the dash ammeter may be relied upon.

Run the engine at a speed high enough for the maximum normal output; loosen the brush holder and move very slowly backward and forward, meanwhile noting the effect on the reading of the ammeter; and mark the point at which the best output is obtained. To test as a motor, connect the ammeter in circuit with half of the battery and run idle. Move brush holder backward or forward to obtain best setting point, as shown by the ammeter reading, which, in this case, will be the minimum instead of the maximum. The unit should not draw more than 7 amperes when tested in this manner. If the best points for generating and running as a motor, as shown by these tests, are separated by any considerable distance, a compromise must be effected by placing the brush holder midway between them. If the dash ammeter does not appear to be correct, check it with the portable instrument or with another dash ammeter.

SPLITDORF SYSTEM

Twelve—Six-Volt; Single-Unit; Two-Wire

Dynamotor. Both windings are connected to the same commutator on the dynamotor, which is of the bipolar type.

Wiring Diagram. As the lamps are run on 6 volts, the 6-cell battery is connected as two units of 3 cells each for lighting, and these units are connected in series-parallel for charging, as the dynamotor produces current at 6 volts. The remaining details of the connections will be clear in the wiring diagram, Fig. 325.

Six-Volt; Two-Unit

Control. *Switch.* The starting switch is mounted on the starting motor. This switch automatically breaks the circuit as soon as the engine starts. The starting gear slides on spiral splines on the armature shaft, so that when the engine gear over-runs it, the starting gear is forced out of engagement. This gear is connected to a drive rod which also engages a switch rod, so that when the gear is forced out of mesh with the flywheel, it carries the switch rod with it and automatically opens the circuit. The switch contacts cannot stick, and no damage can result from holding down the switch pedal after the engine has started.

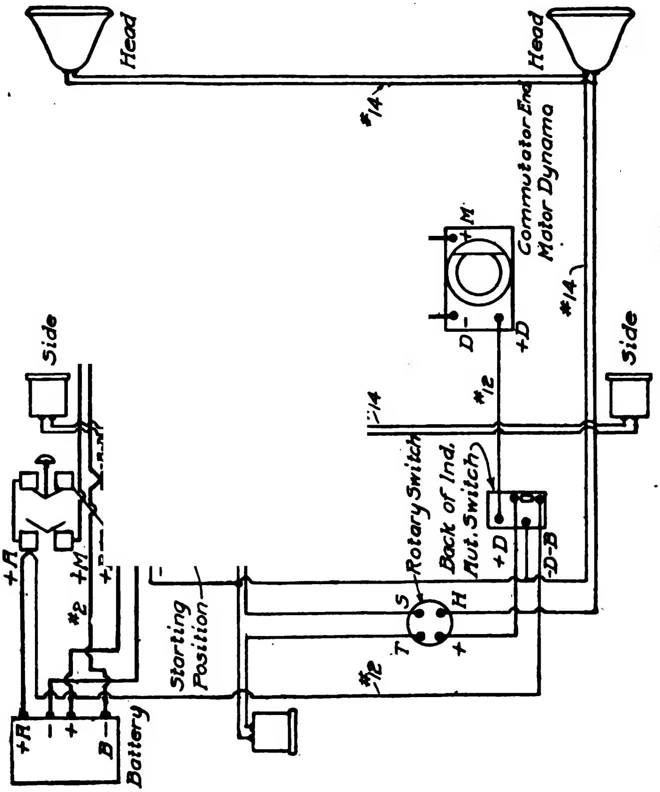


Fig. 325. Wiring Diagram of Splitdorf-Apelco Twelve Six-Volt Single-Unit Two-Wire System

Regulation. On the earlier models, a vibrating regulator was built in the generator, as illustrated in the section on Constant-

Potential Generators, but in later models an external regulator combined with the battery cut-out is employed. This is a constant voltage control of the vibrating type, similar to that described in detail in connection with the Bijur system, i.e., an electromagnet operating two spring-mounted armatures carrying contacts.

Instructions. Should a discharge of 3 amperes or more be indicated on the ammeter when the engine is idle and all lights are off, this can be eliminated by slightly increasing the tension of the spring at the rear end of the cut-in armature.

Too great an increase in the tension of this spring will cause the cut-in, or charging point, to be raised too high, as indicated by the ammeter, which should be noted when making the adjustment.

Fig. 326. Splitdorf VR Regulator
Courtesy of Splitdorf Electric Company, Newark, New Jersey

The voltage regulator as set at the factory is adjusted to limit the output of the generator to from 7 to 10 amperes. Should it be necessary to increase this for winter running or for any other reason, it may be done by increasing the tension of the spring armature. The amount of movement of the adjusting screw at the rear end of the armature that is necessary will be indicated by the reading of the ammeter. The passage of current at the regulating contacts, which are in constant vibration while the engine is running above a certain speed, tends to roughen them. In time this may affect the charging rate and cause the points to stick together, which will be indicated by the ammeter showing a permanent increase in the charging rate. If the latter becomes excessive, the cover of the regulator should be removed, and a thin dental file passed between the contacts on the stationary screw *R*, Fig. 326, and the movable contact on the regulating armature until both become smooth. In case it is necessary to remove the contact screw *R* for the purpose of smoothing its point, be sure to replace it at the same position, taking care that the ammeter reading does not exceed 7 to 10 amperes and that the lock-nut *N* is fastened securely. Under ordinary conditions, these contacts should not require attention on an average oftener than once a year, but it would be well to examine them occasionally.

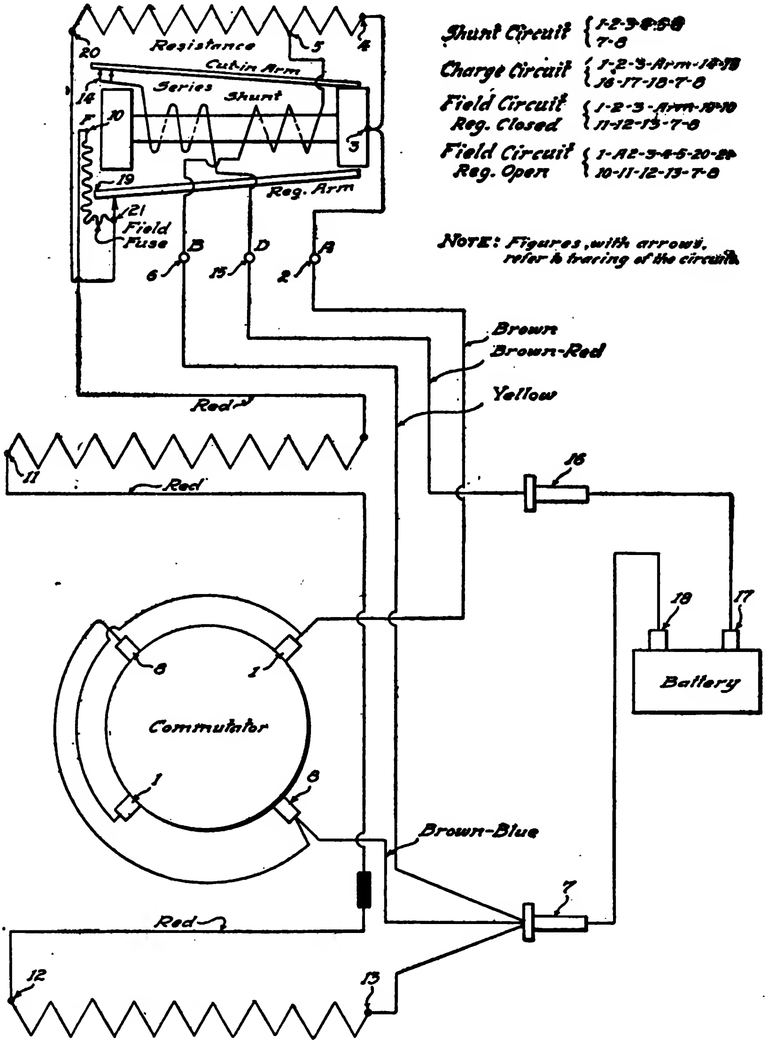


Fig. 327. Wiring Diagram of Splitdorf Lighting Generator and VR Regulator

By referring to Fig. 327, which is a diagram of the wiring of the generator and battery, the relation of these essentials to the regulator and cut-out are made clear. The field fuse shown on this diagram is also indicated at *F* in Fig. 326. This fuse is a small piece of soft-alloy wire mounted between the post *F* and the contact-breaker. By referring to the wiring diagram, it will be noted that this fuse is in the shunt-field circuit, so that if it has been blown, the machine will not generate. It is designed to blow only at high speed with the battery off the line and the vibrator contact *R* stuck. In actual practice, the regulator cut-out is mounted directly on the generator itself. The colors mentioned alongside the different wires are for purposes of identification so that there will be no mistakes in making the various connections.

Starting Motor. The starting motor is of the series-wound type and is similar in design to the generator. It is supplied with a Bendix drive as shown in Fig. 328.

The starting motor is constructed so that when the operator presses the starting switch, the starting circuit is completed and the armature speeds up very rapidly. As the gear is counter weighted and is mounted on a spiral cut sleeve, it is "threaded" into mesh with the flywheel gear when the armature revolved. This spiral cut sleeve holds the gear in mesh while the motor is being cranked. As soon as the engine picks up it turns faster than the starter pinion which is now operated from the flywheel, and on account of the spiral cut sleeve the pinion is forced out of mesh with the flywheel gear. This sleeve, mounted on the armature shaft, is connected to a coil spring, the other end fastened to the armature shaft. The spring takes up the shock.

Fig. 328. Splitdorf SU Starting Motor
Courtesy of Splitdorf Electric Company, Newark, New Jersey

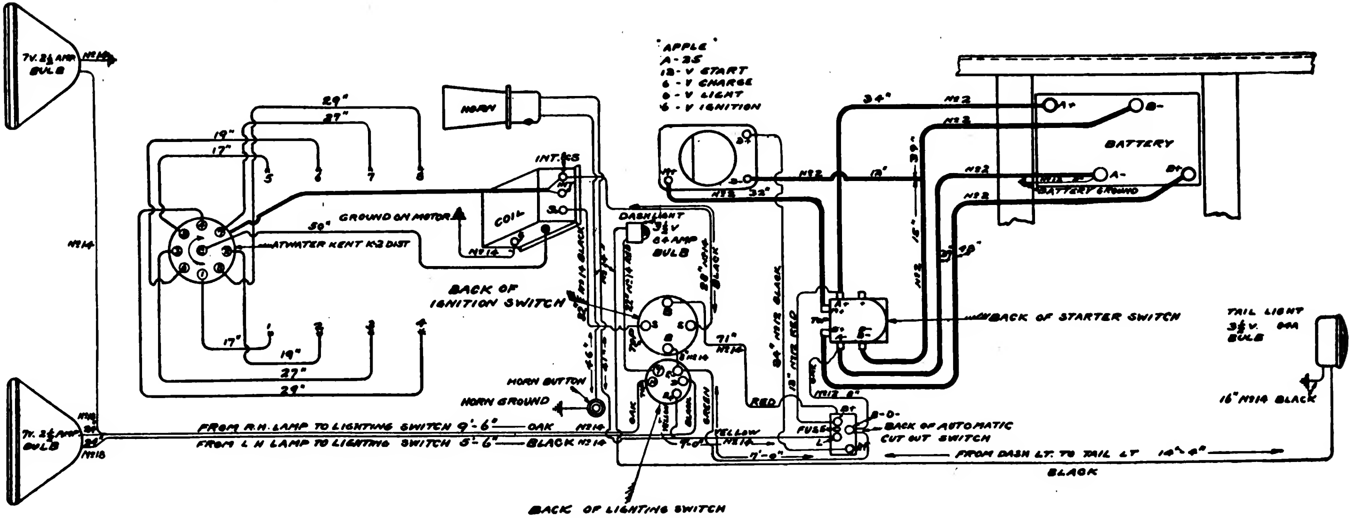
The feature of this construction is, that no matter how long the operator may hold his foot on the starting pedal, the current is broken when the engine starts, as in the manner previously described. The amount of current actually required for turning over the engine is thus controlled by the engine itself, and on account of the positive connection between one element of the switch and the starting gear, all possibility of the jaws of the starting switch sticking is eliminated.

Instructions. Apart from the special adjustments of the starting switch, as mentioned in the description of its operation, the instructions for maintenance are the same as those for other systems. In case this switch does not operate properly, the sequence of operations as mentioned should be checked up, and the distances given verified. In case these distances have become greater through wear, they should be adjusted. To replace the brushes, remove the cover strap over the commutator end of the unit, either generator or motor, put the two screws holding the rocker disc in place, disconnect the brush leads, and withdraw the brushes from the holders. It is important that the brushes slide freely in the holders and that the brush-lead terminals are clean and bright before replacing the terminal screws. See that the springs rest fairly on the ends of the brushes and that their tension has not weakened. Follow instructions given in connection with other systems for care of the commutator.

Failure of Engine to Start. When the starting motor cranks the engine after the starting pedal is depressed but fails to start the engine after a reasonable time, release the starting pedal and ascertain the cause, which may be due to the following: Ignition off, lack of fuel, fuel supply choked, cylinders needing priming due to weather conditions, or cylinders flooded from too much priming.

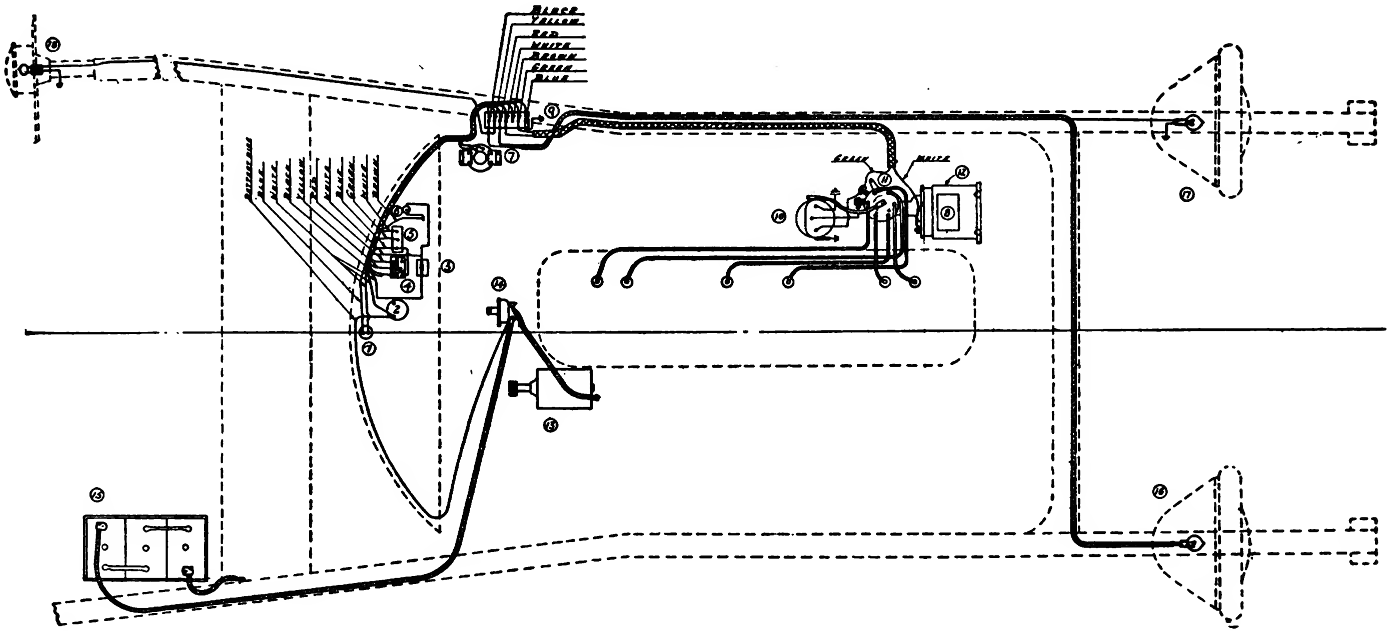
Should the starting motor fail to crank the engine when the starting pedal is fully depressed, there is a possibility that the battery is run down (which condition will be indicated by an excessive dimming of the lights), that there is a loose connection in the starting circuit, or that the starting switch is not making proper contact. The various tests previously given will probably take care of all these conditions.

Oiling of Starting Motor. The starting motor should be oiled once every 500 miles with any medium high-grade oil by applying oil to the cups, switch rods, guide rods, and pawl; also on the compensating device. Starting motors equipped with the Bendix drive are fitted with oil cups at each end of the unit.



Atwater-Kent Ignition and Splitdorf Starting and Lighting Installations on the Hollier Eight

Courtesy of Lewis Spring & Axle Company, Chelsea, Michigan



1 r
2
3
4
5
6
7
8 TOR
9
10 IGNITION COIL
11 IGNITER
12 GENERATOR
13 STARTING MOTOR
14 STARTING SWITCH
15 STORAGE BATTERY
16 RIGHT HAND HEADLIGHT
17 LEFT HAND HEADLIGHT
18 TAIL LIGHT

MODEL D—40

Color	Wire Names and Circuit
BLACK	NEGATIVE SERVICE WIRE FROM NO. 1 ON 4 THROUGH 9 TO 16 AND 17
YELLOW	NEGATIVE SERVICE WIRE FROM NO. 2 ON 4 THROUGH 9 TO 18
RED	DIMMER WIRE FROM NO. 4 ON 4 THROUGH 9 TO 16
WHITE	NEGATIVE DYNAMO WIRE FROM 12 THROUGH 9 TO 2 AND 3
WHITE	NEGATIVE SERVICE WIRE FROM 2 TO "B" ON 5
WHITE	NEGATIVE SERVICE WIRE FROM 3 TO 4 AND 1
BROWN	NEGATIVE SERVICE WIRE FROM 6 TO 7. ENDS IN 9
GREEN	NEGATIVE IGNITION WIRE FROM "C" ON 5 THROUGH 9 TO 11
BLUE	GROUND WIRE FROM 1 AND "G" ON 5 AND 7 THROUGH 9 TO GROUND SCREW

Wiring Diagram for Mitchell-Splitdorf Ignition, Starting, and Lighting Installation on the Mitchell 1917 Cars, Model D-40

Courtesy of Mitchell Motors Company, Racine, Wisconsin

U.S.L. SYSTEM

Twenty-Four—Twelve-Volt, and Twelve—Six-Volt; Single-Unit; Two-Wire

Variations. The 24—12-volt signifies that the starting voltage is 24 and the generating voltage 12, the battery of twelve cells being divided into two groups of six each in series-parallel for charging, while 12—6 signifies that the starting voltage is 12 and the generating voltage 6, the 6-cell battery being divided in the same manner.

The foregoing systems will be found on cars prior to, and including, 1915 models. For 1916 and 1917 models, a 12—12-volt system of the same single-unit two-wire type is standard. In this system the complete battery is used for the lighting as well as the starting, so that charging, lighting, and starting are all at the same voltage, using the complete battery of 6 cells for both of the former.

Generator-Starting Motor. The machine is multipolar (either six or eight poles) and is designed to take the place of the flywheel of the engine. All but the 12—6-volt equipments are made with an outside armature, Fig. 329, i.e., the armature revolving outside of the field poles which it encloses; and the 12—6-volt with an inside armature, Fig. 330. As the armature is mounted directly on the end of the crankshaft, the drive is direct at engine speed whether charging or starting.

Fig. 329. Details of U.S.L. Flywheel Type Dynamotor with Outside Armature
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

One of the advantages of this type of machine, owing to its large size, is its ability to generate an amount of current far in excess of any ordinary requirement. This permits the employment in the inherently regulated type of only three brushes, Fig. 331, when the unit is running as a generator, while all the brushes are employed when it operates as a starting motor. In the types equipped with an external regulator, all the brushes are employed for generating as well as for starting.

Field Poles Armature Brush Cover

Fig. 330. U.S.L. Inside Armature Type Dynamotor (External Regulator)

Top

3 Generating Brushes

Fig. 331. Location of Generating Brushes in U.S.L. Dynamotor

Regulation. The 24—12-volt unit in the U.S.L. system is made with two types of regulation, one type using an external regulator, which is usually mounted on the dash, and the other of the inherent type. The 12—6-volt type has an external regulator. These two types may be distinguished by the presence of the regulator in the charging circuit, which, however, must not be confused with the automatic switch, or battery cut-out, which is only employed on the inherently regulated type. The details of the regulator are shown in Fig. 332, and it will be noted that the regulator also incorporates the battery cut-out as well as an indicating pointer which shows whether the regulator is working properly or not. In operation, the regulator cuts into the generator field circuit a variable resistance consisting of an adjustable carbon pile. The connections of the regulator are shown in the wiring diagrams.

The regulation of the U.S.L. inherent type is accomplished by the combination of a Gramme ring armature, a special arrangement of connections and of the field windings, and the use of only a part of the armature and fields for generating. This method is, of course, special on this make and could not be used on other types of construction. The regulation obtained is based on armature reaction and is similar to that resulting from the third-brush method, but the machine reaches its maximum output at a lower speed than would be possible with the third-brush method and without the employment of a special brush for the purpose.

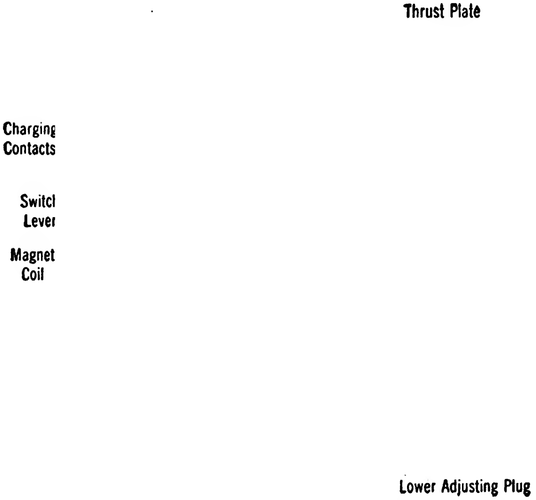


Fig. 332. External Regulator of the U.S.L. System
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

Instruments and Protective Devices. In addition to the indicator, which is combined with the external regulator in the U.S.L. type, an ammeter is also employed to show the rate of charge and discharge.

Two fuses, mounted in clips on the base which holds the battery cut-out, or automatic switch, protect all the circuits. The smaller of these is a 6-ampere fuse and is in the field circuit of the generator, while the larger is a 30-ampere switch and is in the generator charging circuit. This applies only to those inherently regulated equipments fitted with a special type of automatic switch.

Wiring Diagrams. Figs. 333, 334, and 335 show the standard wiring diagrams of the three types mentioned, being, respectively, the 24—12-volt externally regulated type, the 12—6-volt external regulator and internal-armature type, and the 24—12-volt inherently regulated type. In the diagram proper of each of the 24—12-volt types is indicated the layout for using 7-volt lamps, while the extra diagram at the side shows the method of connecting for 14-volt lamps. The "touring switch" shown on the first two diagrams is a hand-operated switch in the charging circuit and is designed to prevent overcharging of the battery when on long day runs. The inherently regulated type requires very little field current, and on most of these the touring switch is of the miniature push-button type, like a lighting switch.

Instructions. *Touring Switch.* On the types equipped with the touring switch, this enables the driver to control the charge. Pulling out the button closes the switch and permits the generator to charge the battery when the engine reaches the proper speed; pushing it in opens the circuit. This switch must always be closed before starting the engine, and it must be kept closed whenever the lights are on and also under average city driving conditions where stops are frequent and but little driving is done at speed. When touring, the switch should be closed for an hour or two and then allowed to remain open during the remainder of the day, as this is sufficient to keep the battery charged, and there is no need for further charging until the lamps are lighted. The best indication of the necessity for opening the touring switch is the state of charge as shown by the hydrometer. The driver should not start on a long day's run with the battery almost fully charged, without first opening the touring switch, as the unnecessary charging will overheat the battery. This switch should be inspected at least once a season. Push in the button to open the circuits, remove the screw at the back and take off the cover. The switch fingers should be bright and make good contact with the contact block; if they do not do so, remove and clean them, as well as the contact pieces on the block. Do not allow tools or other metal to come in contact with the switch parts during the operation, for even though the switch is open, a short-circuit may result; then one of the fuses will blow. In replacing the fingers, bend sufficiently to make good firm contact.

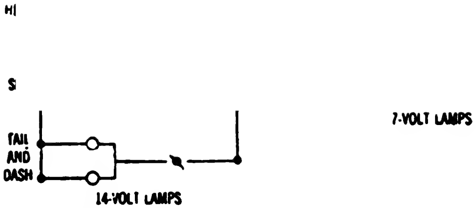


Fig. 333. Wiring Diagram for 24—12-Volt External Regulator Type, U.S.L. System

Fig. 334. Wiring Diagram for 12—6-Volt External Regulator Type, U.S.L. System

14-Volt Lamps 7-Volt Lamps

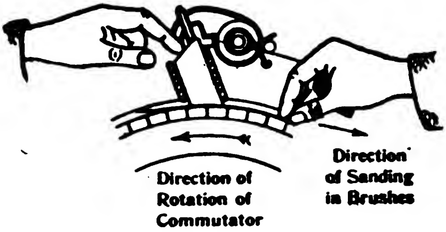
Fig. 335. Wiring Diagram for 24—12-Volt Inherently Regulated Type, U.S.L. System

Starting Switch. The starting switch is filled with oil, and this should be renewed once a year. To do this, the switch must be disconnected, and the screws *A*, Fig. 336, removed; in case the box sticks, insert a screwdriver point between the top of the box and the bottom of the frame and pry loose. To guard against the switch dropping when these screws are removed, hold the hand beneath it while taking them out. Before attempting to remove the switch, disconnect the positive battery connections $B1+$ and $B2+$ at the battery as shown in Fig. 335. These are the two main terminals in the center. It is unnecessary to tape them, as a short-circuit cannot occur. Pour out the old oil, clean out thoroughly with gasoline, allow to dry, and refill with transformer oil or light motor oil to the proper level with the switch box standing plumb. The proper height on the Type E-2 or E-3 box is $1\frac{5}{8}$ inches, on E-4 box $2\frac{3}{4}$ inches. Before putting in the new oil, however, the drum and finger contacts should be examined, and, if pitted or dirty, should be cleaned with a fine file. Make sure that all fingers bear firmly against the drum so as to make good contact; if they do not, remove and bend them slightly to insure this. If the starting switch is abused in operation, or if improper oil containing water or other impurities be used, the contacts will burn and fail to make good electrical connection. The switch box is the only place in the system requiring oil.

Fig. 336. U.S.L. Oil-Filled Starting Switch

Brush Pressures. There is only one adjustment on the generator, viz, the tension of the brush fingers. The brushes should fit freely in their holders so as to transmit the full pressure of the spring against the commutator. The adjustment as made at the factory should not need correction under one or two years of service. Pressures required on the various machines are as follows: for Type E-12 external regulator, $1\frac{3}{4}$ pounds on each brush; $1\frac{1}{4}$ pounds on brushes of all other external-regulator machines; $1\frac{3}{4}$ pounds on each of the three lowest brushes on the inherently regulated type, these being the only brushes used in generating the charging current; $1\frac{1}{4}$ pounds on each of the remaining brushes of the inherently regulated generator. Keep commutator clean, as the chief cause of failure of the inherently regulated type is an excess of oil or dirt or both accumulating on it.

Radial and Angular Brushes. The brushes employed are of two types—radial and angular. Radial brushes are used on external-regulator type generators other than those having "Type E-49" on the name plate; angular brushes are used on Type E-49 and all inherently regulated generators. Each radial brush should bear squarely against that side of its holder toward which the commutator rotates. Each angular brush should bear squarely against that side of its pocket away from which the commutator rotates. To sand-in old brushes or fit new brushes properly, insert a strip of No. 00 sandpaper (never use emery, paper, or cloth), between the commutator and the brush, press down on top of brush and draw sandpaper under it, Fig. 337. If the brush is *radial*, draw the sandpaper in the direction of commutator rotation; if *angular*, draw the sandpaper in the direction opposite to that of commutator rotation. No oil is needed on the commutator as the brushes themselves contain all the lubricant necessary. Fine sandpaper, as mentioned above, may be used for cleaning the commutator when necessary, the engine being allowed to turn over slowly during the operation.



Angular Brush

Radial Brush

Fig. 337. Methods of Sanding-In Brushes on Dynamotor

External Regulator. Should the automatic-switch (cut-out) member of the regulator remain closed with the engine stopped, start the engine at once, and the switch lever should open. If it does not, remove the regulator cover (with the engine running) and pull the lever open by hand. When the switch lever is correctly set, a slight discharge will be noted on the ammeter the moment the switch lever opens. This discharge reading should not exceed 4 amperes; if in excess of this, increase the tension of the switch-lever spring by releasing the lock nut on the left side of the plate and turning up on the nut at the right until the proper adjustment is secured, then retighten the lock nut. The indicating pointer is moved by the switch lever in closing, and when it appears in its upper position through the sight glass on the cover, the battery is charging; when the switch lever opens, the pointer drops against its stop by gravity.

When the battery shows a lack of capacity, the battery itself and all connections and fuses being in good condition, note the amount of charging current indicated by the ammeter. If the maximum current (external-regulator type) shown by the ammeter does not exceed 10 to 12 amperes at full engine speed after the engine has been running for fifteen minutes, see that the brushes and commutator are in good condition—wipe off the commutator with a dry cloth, and, if necessary, sand-in the brushes to a good seat. If this does not increase the generator output as shown by the ammeter, test the latter as already noted, i.e., see whether the pointer is binding and, if not, check with the portable testing instrument or another ammeter of the dash type. Should none of these remedies correct the fault, *screw in* the lower adjusting plug of the carbon-pile lever slowly, noting the effect on the ammeter reading as the adjustment is made.

With the external regulator, the charging current should not exceed 18 amperes at the highest engine speed. If, at any time, the ammeter shows a higher reading than this, *screw out* the lower adjusting plug of the carbon-pile lever slowly to decrease the current, stopping when the indication does not go above 18 amperes at full speed.

After making this adjustment of the lower plug, make sure that the carbon-pile lever air gap does not exceed $\frac{1}{8}$ inch, and is not less than $\frac{3}{32}$-inch when the engine is stopped. If the gap is too small the switch lever will vibrate rapidly at high engine speeds. When necessary to adjust this gap, screw the upper adjusting plug in or out, but, after doing so, the current output must be checked and adjusted by means of the lower adjusting plug. Always tighten the adjustment clamping screws after setting either of the adjusting plugs.

Testing Carbon Pile. If the automatic-switch unit of the generator does not cut in with the engine running at speed equivalent to 10 to 14 miles per hour, test the carbon pile by short-circuiting the terminals $F+$ and $A+$ of the generator with the blade of a screwdriver. Speed up the engine slowly and note whether the generator cuts in much sooner than when the terminals are not short-circuited. Do not run the engine at high speed, nor for any length of time with the terminals short-circuited, as an excessive amount of current would be generated. If the generator does cut in much earlier with the terminals short-circuited than without this, the carbon pile needs cleaning. Should the generator not cut in earlier or should it fail to operate altogether, when the carbon pile is short-circuited the trouble is probably in the brushes of the generator or in the touring switch.

To clean the carbon pile, proceed as follows: Unscrew the plug at the upper end of the glass rod and remove the rod; if any of the discs are pitted or burned, rub them together or against a smooth board to make them smooth and flat. Remove the end carbons and clean the brass plates with fine sandpaper, if necessary. In replacing end carbons, make sure that they fit firmly against the brass end plates and that the screw heads do not project beyond the faces of the carbon discs. After reassembling the carbon pile, the regulator will need adjustment for current output, as previously noted.

If for any reason it becomes necessary to disconnect the battery, either open the touring switch and block it open so that it cannot be closed accidentally if the car is to be run, or disconnect and tape the right-hand regulator terminal $A+$. Otherwise, the machine will be damaged by operating.

Battery Cut-Out. Should either of the fuses mounted on the automatic switch of the inherently regulated type blow, immediately open the touring switch. A loose connection or a short-circuit is probably the cause, and the touring switch should not be closed again until the cause has been located.

Ammeter. The ammeter should be checked at least once a year by comparing it with a standard instrument, such as the portable outfit mentioned previously, or any other suitable low-reading ammeter of known accuracy. To do this, disconnect the positive wire from the ammeter on the dash and connect it to the positive terminal of the standard ammeter used for testing; then connect a wire between

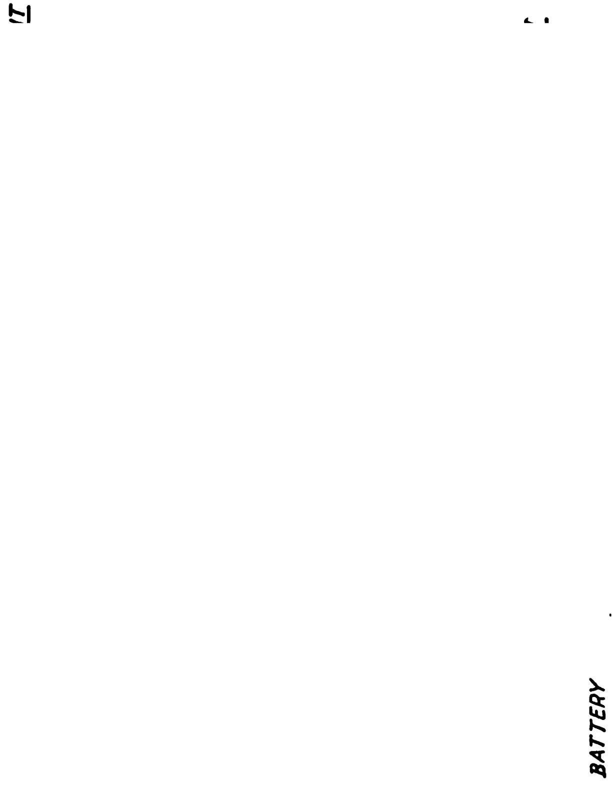


Fig. 338. Wiring Diagram of U.S.L. System on 1917 Mercer Cars

the negative terminal of the standard ammeter and the positive terminal of the dash ammeter. With the engine running at various speeds, take simultaneous readings of both instruments; any difference between the two should be taken into consideration thereafter when reading the dash ammeter. Unless a test of this kind is carried out, the battery may be receiving either an insufficient or an excessive charge while the ammeter indicates the proper amount.

U.S.L. 12-Volt System. The U.S.L. 12-volt system generates and starts at 12 volts and is standard on the 1916 and 1917 models of the Mercer, Fig. 338. It differs from the other systems in having a magnetically operated starting switch and a centralized control unit, which incorporates all the controlling devices of the entire system, the cut-out, the ammeter, fuse blocks for generator and lighting circuits, starting switch, touring switch, head, side, and tail-light switches, all of which are operated by push buttons. All of these switch buttons, as well as the fuses, are locked in place, while the buttons may be locked in any desired combination of positions.

Fig. 339. U.S.L. Type E-14 Starting Switch

Starting Switch. This is of the magnetically operated type and is mounted on the top of the field-mounting frame. It operates by means of a solenoid and plunger, as illustrated in Fig. 339. Control is by means of a spring push button on the control unit marked "start", Fig. 340. When this button is pushed in, it energizes the solenoid of the starting switch, which causes the plunger to close the contacts. Releasing the button on the control unit breaks the circuit, and the switch itself is then opened automatically by a self-contained spring. With this method of control, the current is only on as long as the starting button is held in.

Fig. 340. U.S.L. Control Panel as Mounted on Dash of Mercer Cars

Fuse Blocks. There are two of these, the smaller, illustrated in Fig. 341, being the generator fuse block. This contains only two fuses, a large one *9* of 30-ampere capacity in the generator-battery charging circuit, and a smaller one *8* of 5-ampere capacity in the generator shunt-field circuit. Should either fuse blow, immediately push in the touring-switch button, as a short-circuit or an open or a loose connection is probably the cause. After locating the trouble, remove the generator fuse block from the instrument board. To do this, unlock the knob, press it inward, and turn ¼ revolution to the right or to the left. Replace with spare fuses carried in the light fuse block, return the generator fuse block to its original position, and lock.

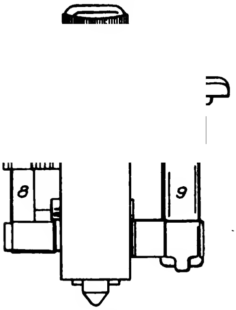
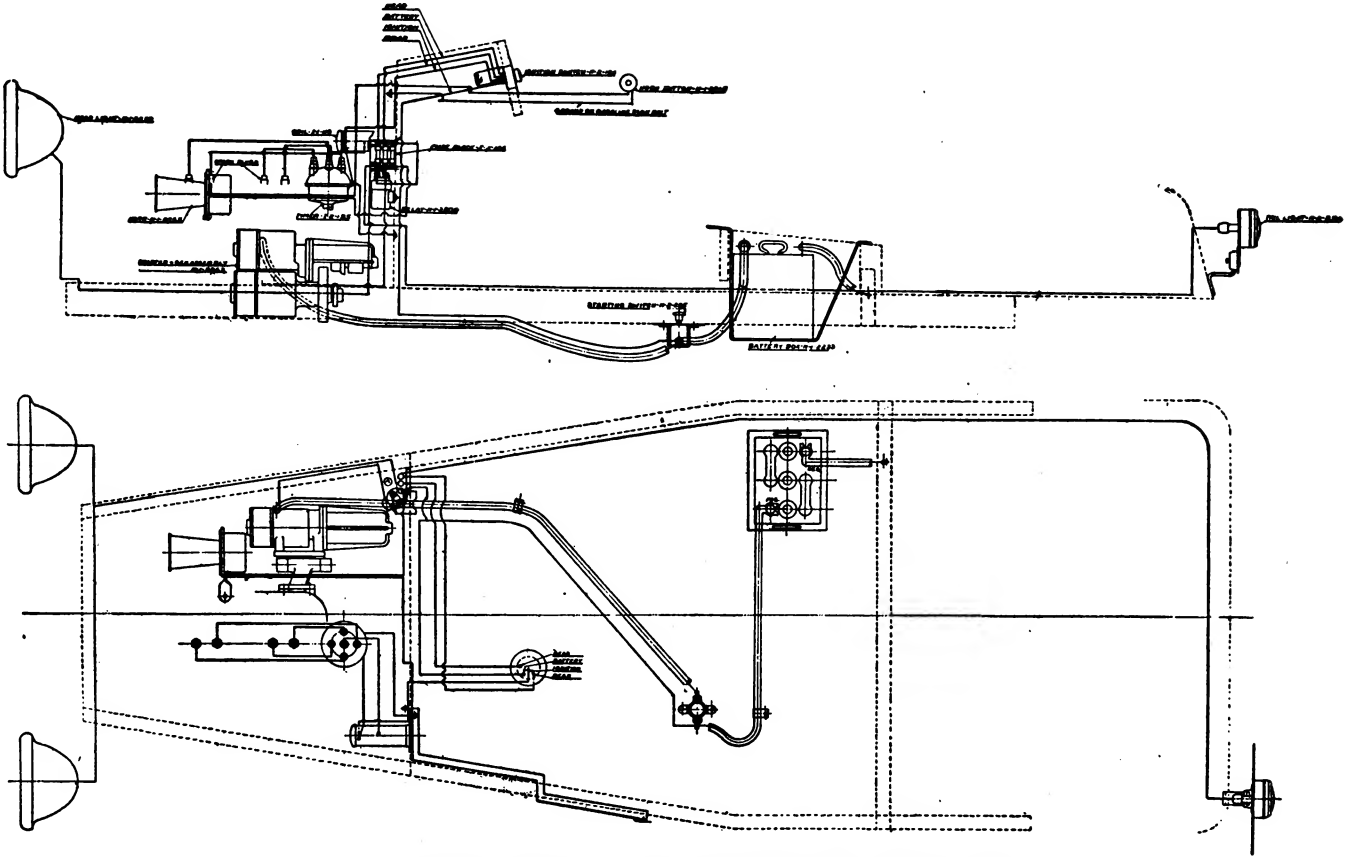


Fig. 341. U.S.L. Generator Fuse Block

The light fuse block, which is shown in Fig. 342, carries a total of seven fuses, of which four are in active use, while the remaining three are spare fuses for use in replacing blown fuses. On the right-side view of this fuse block there appear two large fuses *6* and *7*. Fuse *7* is a protecting link in the ground-return wire of the lighting and horn circuits. The small fuse *5* is of 10-ampere capacity and, together with fuse *6* of 30-ampere capacity, is a spare fuse for emergency use. On the left side of the block are three active fuses *1*, *3*, and *4* of 10-ampere capacity; and one spare fuse *2* of 5-ampere capacity. Fuse *1* is in the horn circuit, fuse *3* in the headlight circuit, and fuse *4* is common to the tail-, dash-, and side-light circuits. Should any of the fuses on this block blow, the trouble is probably a short-circuit on the frame of the car which should be remedied before the fuse is replaced. Instructions

Fig. 342. U.S.L. Left-Hand Side and Right-Hand Side Light Fuse Blocks



Wagner Ignition, Starting, and Lighting Installation on Saxon Four-Cylinder 1917 Roadsters. Models B-5-R and B-6-R
Courtesy of Saxon Motor Car Corporation, Detroit, Michigan

Wagner Ignition, Starting, and Lighting Installation on Saxon 1917 Six-Cylinder Cars, Models S-3-T, S-4-T and S-4-R

Courtesy of Saxon Motor Car Corporation, Detroit, Michigan for the use of the touring switch in this system are the same as previously given.

U.S. Nelson System. This type has been specially designed for the Nelson car, which first appeared in 1917, and it differs radically from those already described in that it is carried on the forward end of the engine crankshaft instead of at the rear. The brushes bear on the inside face of the commutator and may be reached through three openings in the armature support. To clean the commutator in this type, it is necessary to turn the armature so that three of the six brushes appear opposite these openings. Fold a small piece of sandpaper into a square over one of the brushes and allow the engine to turn over for a few minutes. Stop the engine and remove the sandpaper through one of the openings. The engine carries a flywheel at the rear, as usual, and this provision of flywheel weight at both ends of the crankshaft is said to minimize vibration almost to the vanishing point while making possible extremely high speeds.

WAGNER SYSTEM

Twelve-Volt; Single-Unit; Two-Wire (Early Model)

Dynamotor. The bipolar-type dynamotor has both the series and the shunt-windings, i.e., of generator and motor, connected to the same commutator. It is driven direct as a generator, and through a special planetary gear when operating as a starting motor.

Regulation. The regulation is of the inherent type; utilizing the generator winding to weaken the field with increase in speed, i.e., a bucking coil.

Wiring Diagram. *Single-Unit Type.* The left side of the lower half of the diagram, Fig. 343, illustrates the connections when the unit is being used as a starter, as indicated by the arrow showing the direction of rotation of the armature. Those at the right are the running connections, the armature then rotating in the reverse direction and generating current to charge the battery.

Control; Transmission. *Switch.* This is a special type of drum switch mounted directly on the dynamotor on the same base with the battery cut-out. As shown in Fig. 344, when the lever Q is thrown to the left for starting, it also serves to tighten the brake band on the planetary gear. When moved in the opposite direction, it releases this brake, and another set of contacts on the drum of the switch connect the generator for charging. Fig. 345 shows the details of this switch: *A*, *B*, and *C* are the contacts on the starting side, while *H*, *G*, and *F* are the running-position contacts, as shown in Fig. 343. The segments *E* and *L* on the drum contact with the fingers mentioned when the drum is revolved part way in either direction by the lever, shown at the right, which engages the shaft *M*.

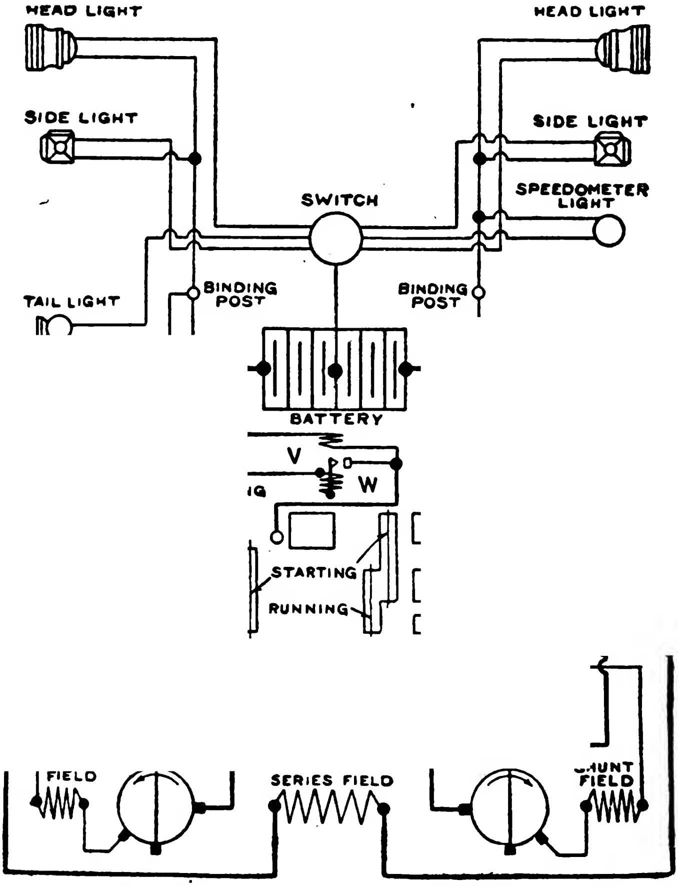


Fig. 343. Wiring Diagram for Wagner Twelve-Volt Single-Unit Two-Wire System (Early Model)

Battery Cut-Out. This is of conventional design. For description and explanation of operation, see previous systems in which a battery cut-out, or automatic switch, is employed. Methods of locating trouble are given in connection with instructions farther along.

Fig. 344. Wagner Control Switch of Drum Type. A—Starter Frame; B—Switch Support; C—Outside End Plate Gear Box; D—Return Spring; F—Oil Hole Screw; G—Self-Closing Oiler; H—Oil Plug; J—Connecting Rod; K—Brake Band; M—Battery Leads; N—End Plate Screws; O—Back End Plate Shield; Q—Starting Switch Lever; R—Brake Band Lever; S—Front End Plate Shield

Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Fig. 345. Exploded View of Drum Switch. A, B, F, G, H, and K—Contact Screws to Contact; C—Auxiliary Contact Finger; E—Drum Contact; J—Screw Holding C; L—Auxiliary Drum Contact; M—Shaft

Planetary Gear. The external form of the different gear boxes used on the early-model single-unit Wagner starter is the same, but their internal construction differs somewhat. The details of the two types employed are shown in Figs. 346 and 347. The principle employed is that of the planetary gear as used to obtain first,

A

Fig. 346. Exploded View of Planetary Gear Transmission. A—Planetary Pinion; B—Rolling Pawl; C—Center Pinion; D—Planetary Hub; E—Pawl Seat; F—Pawl Plunger; G—Internal Gear; H—Inside End Plate; J—Outside End Plate; K—Oil Plug; M—Sheet-Steel Disc

Fig. 347. Assembled Planetary Gear. Letters same as Fig. 346

or low, and high speeds on early-model light cars. The unit consists of a central, or sun, gear *C*, Fig. 347, and three planet pinions *A* meshing with the central gear and also with the internal gear ring *G*. For starting, the tightening of the brake band on the outer groove of the internal gear holds it fast, so that the drive is through the central gear and the reducing pinions in engagement with it and the gear ring, while, for running, the rollers *B* in the clutch *D* lock the gears together so that when generating the gear revolves idly as a unit.

Instructions. The instructions previously given in connection with other systems apply here. For failure to generate, lack of capacity, grounds, or short-circuits in windings, and for keeping the commutator and brushes in condition, see instructions already given, as well as Summary of Instructions, Part VIII.

Fig. 348. Jig for Holding Armature and Tooling Commutator

Method of Tooling Commutator. A different method of undercutting the mica of the commutator is recommended from that already described in connection with the Delco system. This is illustrated in Fig. 348. The armature is removed from the generator and mounted in a simple jig, as shown. The jig is made of 1-inch oak, while ordinary machine screws held in place by lock nuts are utilized as the centers. The bar, or guide, on which the cutter operates, can be made of ½-inch rolled-steel rod, while the cutter itself should be made of ¼-inch drill rod. The point of this cutter is ground sharp, like the parting tool used on a lathe or planer, to the thickness of the mica between the commutator bars. The cutter is moved backward and forward on its guide in the same manner as a planer or shaper tool, and the armature is rotated one segment at a time to bring the mica sections under the tool successively. Where there is not sufficient work of this nature to make it worth while to build the jig, a simple hand tool may be used, Fig. 349. This can be made of a discarded hacksaw blade or a new one, about 8 inches long. One of the ends is ground similarly to the cutter described for the jig, while the other should be shaped like a hook, having the same kind of point as the cutter end. Around the center of this tool should be folded a piece of heavy tin (sheet iron) and the whole wrapped with electric tape. This will prevent the brittle saw blade from breaking and make it much easier to handle. The mica is removed by forcing the sharp end of the tool from the outer edge of the commutator surface to the inner edge, and the rough cut thus made is finished by drawing the hooked end of the tool back through the groove in the opposite direction. To do the job properly, the armature should be held in a vise, otherwise it is liable to move, or the tool is liable to slip, and the copper be cut away with very poor results. Fig. 350 shows the commutator before and after undercutting the mica.

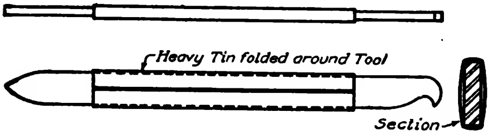


Fig. 349. Diagram of Simple Hand Device for Tooling Commutator

A needle-pointed tool should never be used, as it will simply, make a V-shaped cut in the mica, removing too much in depth and not enough in width. The mica must be cut out clean and square, and a small magnifying glass should be used to see that all of the pieces adjacent to the bars have been removed. After removing the mica, the armature should be placed in a lathe, and a light cut taken from the commutators, i.e., just enough to remove all roughness

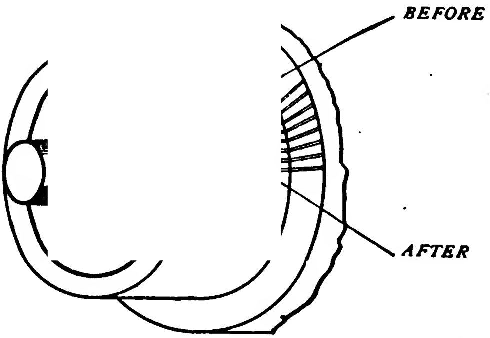
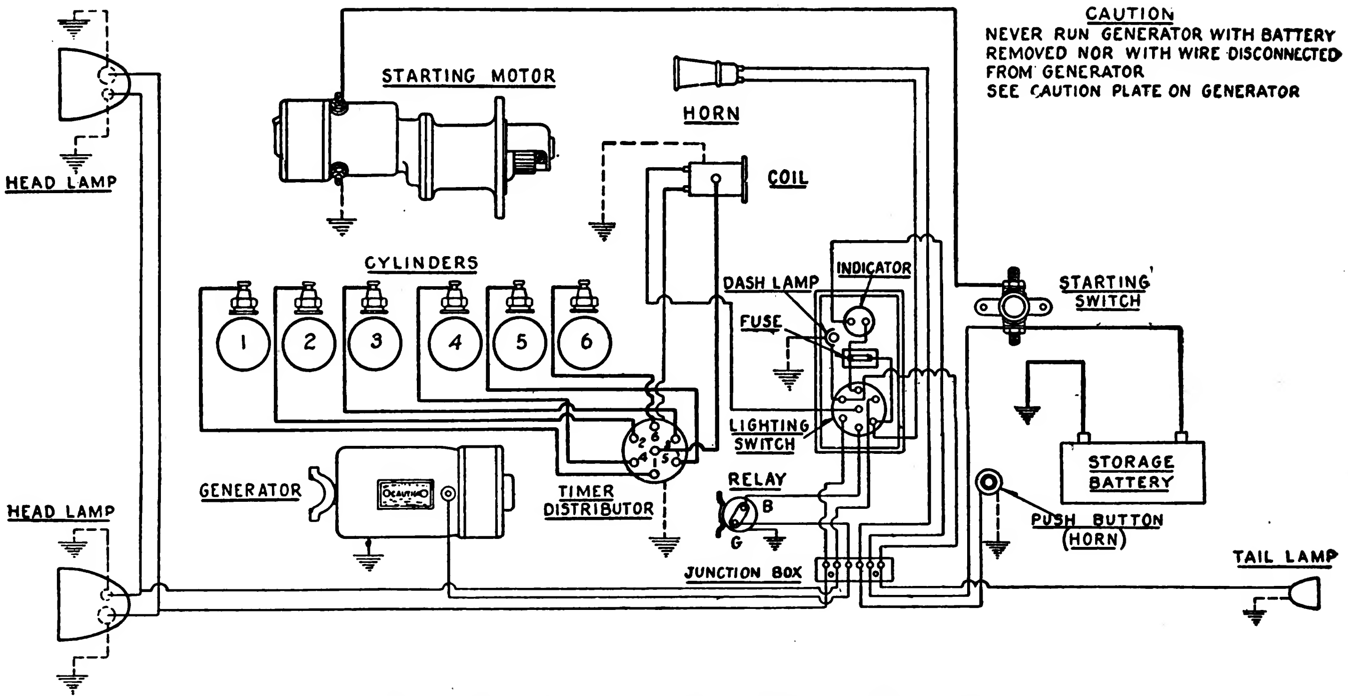


Fig. 350. Diagram Showing Commutator Sections before and after Tooling



Wagner Ignition, Starting, and Lighting Installation on Elgin 1917 Sixes
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Wiring Diagram for Wagner Ignition, Starting, and Lighting Installation on the 1918 Elgin Car
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

and flat spots. The cutting tool employed should be very sharp, so that the soft copper will not be dragged from one segment to another. After turning, fine sandpaper should be used to smooth the commutator. Whether the brushes are replaced with new ones or the old ones are retained, they must be sanded-in to the commutator (see Delco instructions). The springs also should be tested for tension; they must never be allowed to become loose enough to permit the brushes to chatter when the generator is running, as this would interfere seriously with its output.

Lack of Capacity through Faulty Gear Box. Should the battery not charge properly, note whether in starting the lights brighten perceptibly with the car running below 5 miles per hour, while at high speed they remain dim. This indicates that the brake band of the gear box does not release, owing either to improper adjustment of the tightening screw or to something getting between the band and drum. To remedy, the band adjusting screw should be turned until the band feels free when the starting lever is in the running position. If something has caught between the band and the drum, its removal usually will be the only remedy necessary.

Fig. 351. Method of Pulling Wagner Gear Box with a "Come Along"
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Should the battery show signs of exhaustion, and if there is no noticeable increase in the brightness of the lamps when the car reaches a speed of 10 miles per hour or its equivalent, the trouble probably is in the gear box. Remove the front end plate and note if the commutator is rotating. If not, and the reason therefor is not apparent on an inspection of the gears, it may be necessary to remove the gear box. A "come along", such as is employed for taking off Ford wheels, is necessary for this, Fig. 351. It may be found that some of the parts need replacement, or that an entirely new gear box is necessary.

Failure Due to Battery Cut-Out. If the failure to charge the battery be not due to the gear box, remove the cover of the cut-out and see if it is operating properly. When the engine is running at a speed equivalent to 15 miles per hour, the contact should spring away from the adjusting screw. If it does not, connect a voltmeter across the terminals *B* and *H* of the switch, Fig. 352. Should the voltmeter needle not move, examine the contact fingers connected to the studs *C* and *F* and see that they make firm contact with the drum of the switch. Place the end of a pencil on the contact finger *D* and bear down lightly; if the main contact maker then springs away from the adjusting screw, the cause of the trouble is an open circuit at this contact. Bend *D* so that it bears down on the drum segments; should the contacts not close on making this test, the trouble will be an open connection, either in the generator itself or between the generator and the cut-out (switch).

Fig. 352. Details of Wagner Starting Switch. A and B—Large Contact Finger; C—Auxiliary Contact Finger; D—Auxiliary Contact; E—Drum Switch; F, G, and H—Drum Switch Studs; J—Screw Leading to C; Q—Starting Switch Lever

Should the voltmeter give a reading of 6 volts while the contacts do not close, it shows that the shunt coil of the cut-out is open and indicates that its connections are broken or that the trouble is in the coil itself. This may be confirmed by operating the contacts by hand—pushing the contact away from the adjusting screw until it touches the stationary contact. If it remains in that position, the generator is charging the battery, but the shunt coil of the cut-out is out of action and the cut-out will function automatically as it should.

If, under the conditions mentioned in the first paragraph under this heading, the cut-out closes, connect the voltmeter as described and accelerate the engine to a speed corresponding to 25 miles per hour. If the reading is then 15 to 20 volts, the trouble may be looked for in a break in the generator connection to the cut-out. Should it not be possible to locate any break, it may be in the series coil of the cut-out, in which case a new cut-out will be necessary.

Switch or Generator Parts to Be Adjusted. If the starting lever of the switch is not returning to the proper position for running after starting the engine, it will be indicated by a low battery and dim lights. Adjust so that the lever will go to correct position for running and see that the contact fingers of the switch are making proper contact with the drum.

In case the battery does not get sufficient charge, connect an ammeter to the terminal *D* of the switch and to *W* of the cut-out. At a speed equivalent to 15 miles per hour, the ammeter should read 7 to 9 amperes if the generator is working properly. If it does not, examine the commutator, brushes, and wiring, as previously described.

Six-Volt; Two-Unit

General Characteristics. This type is similar in characteristics to most of the other makes of this class already described.

Generator. The generator is the multipolar (four-pole) shunt-wound type.

Regulation. The regulation is of the inherent or bucking-coil type, integral with the field windings of the generator.

Starting Motor. The motor is four-pole and series-wound, driving through a reducing gear mounted on the motor housing, Fig. 353.

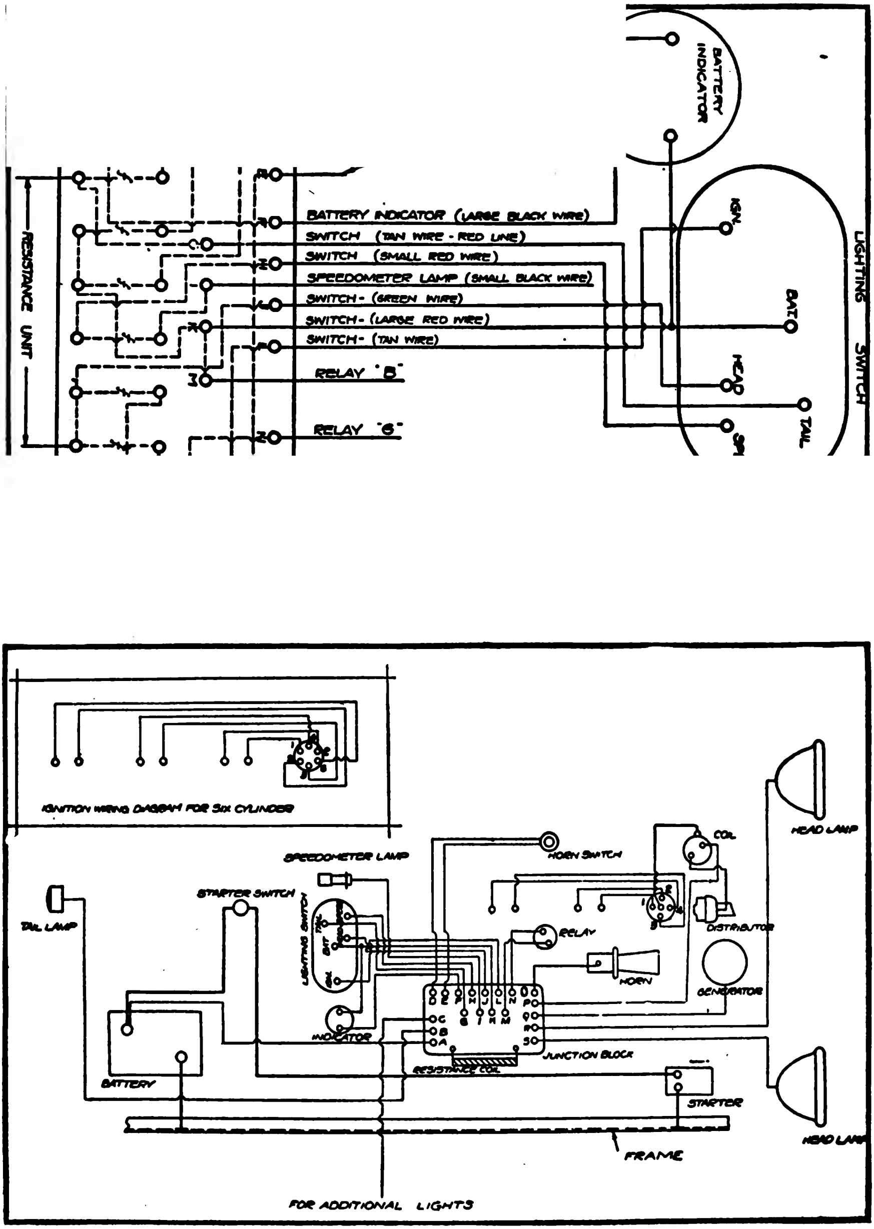
Control. *Battery Cut-Out.* The complete instrument, minus its cover, is shown in Fig. 354. It is of standard design and is intended to be mounted in the tool box under the driver's seat. As shown in the photograph, the upper binding post is the series-coil connection, the central binding post just below it is the shunt-coil connection, while the lowest binding post is a connection completing the circuit through both coils to the battery.

Fig. 353. Wagner Six-Volt Two-Unit Type Starting Motor. Left—Commutator End; Right—Gear End
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Switch. The switch is of the circular knife-blade type, two sets of spring contacts close together being pressed down over the stationary contact against the spring, as shown in Fig. 355 which illustrates the parts of the switch.

Wiring Diagram. A typical wiring diagram of the Wagner two-unit system as installed on the Scripps-Booth four- and eight-cylinder models is shown in Fig. 356. The only difference in the wiring of the two models has to do with the ignition and merely affects the distributor connections, as illustrated by the panel in the upper right-hand corner, which shows the distributor and connections for the four-cylinder car. As the system is a single-wire type, one side of every circuit is grounded, the spark plugs themselves representing the grounded side of the high-tension ignition

Fig. 354. Wagner Cut-Out



Remy Ignition and Wagner Starting and Lighting Installations on Studebaker Four and Six, Models SF and ED. Upper Diagram Shows Junction-Block Wiring Diagram; Lower Diagram Shows Car Wiring Diagram

Courtesy of The Studebaker Corporation of America, Detroit, Michigan

Wiring Diagram for Wagner Ignition, Starting, and Lighting Installation on the 1918 Grant Six
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

circuit. The caution on the diagram—*Never run generator with battery removed from car nor with wire disconnected from generator*—applies not only to the Wagner system but to practically every other system as well.

Instructions. *Ground in Starting or in Lighting Circuits.* When the blowing of a fuse on one of the lighting circuits is due to a ground, or a similar fault is suspected in the starting system, it may be tested for either with the lamp outfit already described or with the low-reading voltmeter, as follows:

Disconnect one battery terminal, taping the bare end to prevent contact with any metal parts of the car, and connect one side of the voltmeter to this terminal. Attach a length of wire having a bared end to the other terminal of the voltmeter, as shown in Fig. 357. Connect the bared end of the free wire to some part of the car frame; making certain that good electrical contact is made. Disconnect the generator and starting motor completely, open all lighting switches, and be sure that ignition switch is off. If there is no ground in the circuit, the voltmeter will give no indication. Be sure that none of the disconnected terminals is touching the engine or frame; to insure this, tape them.

Fig. 355. Details of Wagner Switch
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Should the voltmeter give a reading of 4 volts or more, it indicates that there is a ground in the wiring between the battery and the junction box, or in the wiring between the junction box and the generator or the starting motor. If the voltmeter reads less than 4 volts but more than ½ volt, all wiring and connections should be carefully inspected for faults. This test should be repeated by reversing the connections, that is, by reconnecting the wires on the side of the battery circuit that has been opened and disconnecting the other side.

SIGN ▶ INDICATES GROUND JUNCTION SCREWS IN DASH

Fig. 356. Wagner Two-Unit System for Scripps-Booth Four- and Eight-Cylinder Models

Localizing Any Ground. To localize any fault that the reading of the voltmeter may show, reconnect the wires to the starting motor and close the starting switch; any reading of the voltmeter with such connections will indicate that the ground is in this circuit. Should no ground be indicated with these connections, disconnect the starter again and reconnect the generator; if the voltmeter records any voltage, the ground is in the generator circuit. With both starter and generator disconnected, the voltmeter being connected first to one side of the battery and then to the other, operate the lighting switches, the ignition switch, and the horn, one at a time, and note whether the voltmeter needle moves upon closing any of these switches. A voltage reading upon closing any of these switches will indicate a ground in that particular circuit.

Fig. 357. Testing for Grounds with Voltmeter in Two-Wire System

Short-Circuit Tests. To test for short-circuits, substitute the ammeter for the voltmeter, but do not connect the instrument to the battery. The shunt reading to 20 amperes should be employed, one side of the ammeter being grounded on the frame as previously described, and the other being connected with a short wire that can be touched to the open side of the bat-

Fig. 358. Testing for Short-Circuits with Ammeter in Two-Wire System

tery, Fig. 358. Disconnect the starter and the generator and open all the switches, then touch the bare end of the wire to the battery terminal on the open side as shown. Any reading, no matter how small, will indicate a short-circuit (two-wire system) in the wiring between the battery and junction box or between the latter and the starter, or generator. If the ammeter reading shows a heavy current, there is a severe short-circuit.

Localizing a Short-Circuit. The short-circuit may be localized in the same manner as described for the voltmeter test, i.e., connect the starter and test; disconnect the starter, connect the generator and test. A reading on the generator test may be due to the contacts of the cut-out sticking together. If the cut-out contacts are open and the ammeter registers, there is a short-circuit in the generator windings.

Disconnect the generator again, remove all the lamps from the sockets, and turn on the lighting-circuit switches one at a time, touching the wire to the battery terminal after closing each switch. A reading with any particular switch on indicates a short-circuit in the wiring of the lamps controlled by that switch. Only one switch should be closed at a time, all others then being open. This test should be made also with the ignition switch on but with the engine idle. The ammeter then should register the ignition current, which should not exceed 4 to 5 amperes. If greater than this, the ignition circuit should be examined.

Cautions. Do not attempt to test the starter circuit with the ammeter as it will damage the instrument. To test the starter circuit, reconnect as for operating, removing the ammeter. Close the starting switch; a short-circuit in the wiring will result either in failure to operate or in slow turning over of the engine. See that the switch parts are clean and that they make good contact. If the short-circuit is in the winding of the starting motor, there will be an odor of burning insulation or smoke.

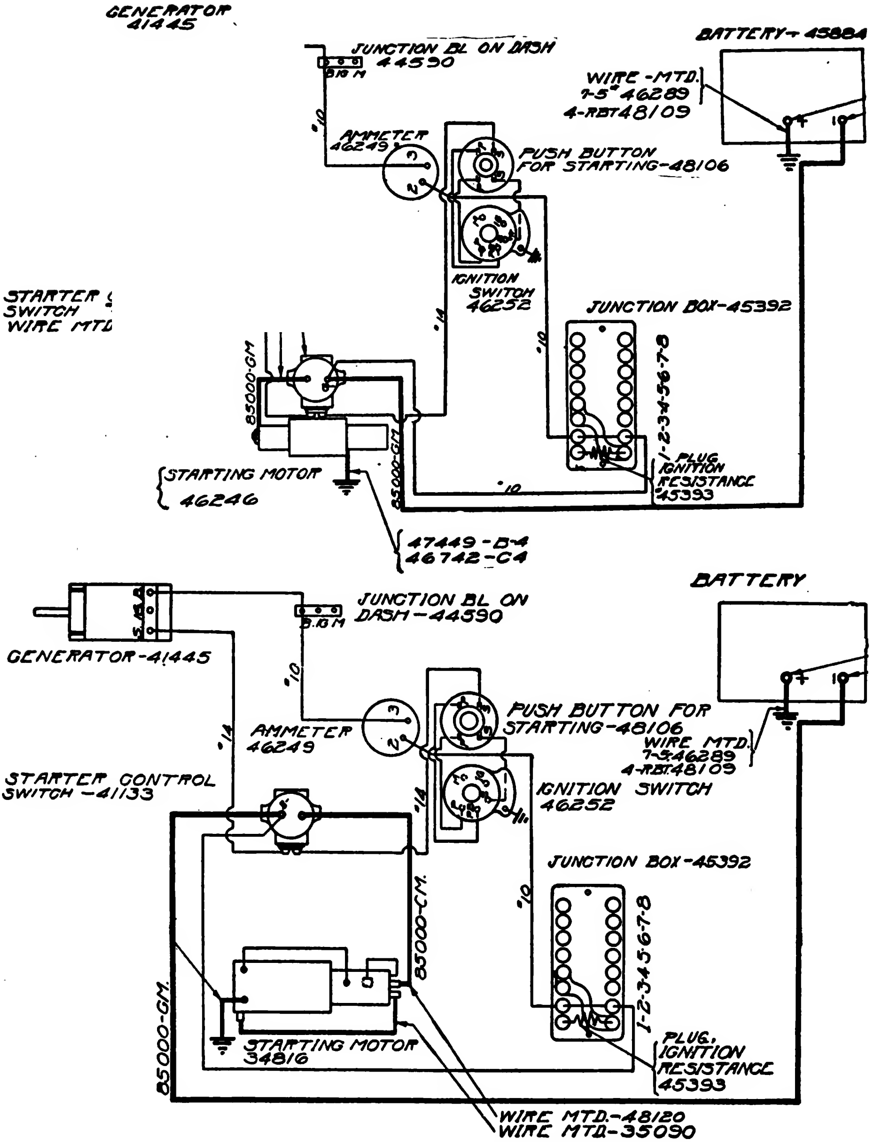
The battery must be fully charged for making any of these tests. While the effect either of a ground or of a short-circuit will be substantially the same, its location and the remedy will be more easily determined by ascertaining whether it is the one or the other. Instructions for making these tests have already been discussed in the Gray & Davis section.

Bosch Ignition Wiring Diagram on Pierce-Arrow Series Four Cars, Models 38, 48 and 66
Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York

SIDE LAMP

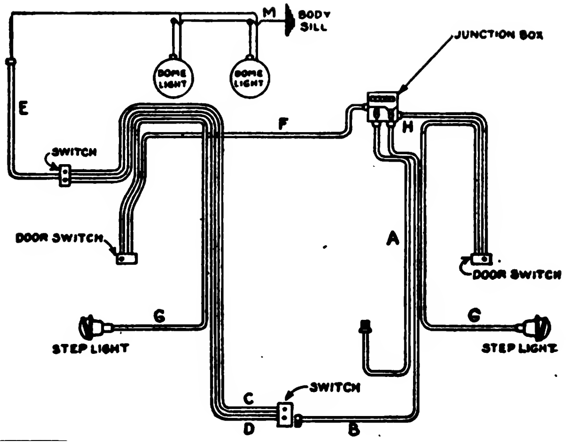
SIDE LAMP
4 C.P. 6 V

Westinghouse Lighting Diagram for Pierce-Arrow Series Four Enclosed Cars, Models 38, 48 and 66
Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York



Westinghouse Starter Intallation on Pierce-Arrow Series Four Cars. Upper Diagram for Models 38 and 48; Lower Diagram for Model 66

Courtesy of Pierce-Arrow Motor Car Company, Buffalo, New York



Westinghouse Starting and Lighting Installation on Locomobile Series Two Six-Cylinder Cars, Models 38 and 48. Upper Diagram Layout of Cables on Closed Cars; Lower Diagram Complete Wiring Circuits for Open Cars

Courtesy of The Locomobile Company of America, Bridgeport, Connecticut

Remy Ignition and Westinghouse Starting and Lighting
Courtesy of H A L Motor Car Company, Cleveland, Ohio

Connecticut Ignition and Westinghouse Starting and Lighting Installations on the Lexington, Series 6-0-17 and 6-00-17
Courtesy of The Lexington-Howard Company, Connersville, Indiana

WESTINGHOUSE SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. The single unit of the 12-volt system, or the "motor-and-generator" as the manufacturers term it, is a bipolar machine, both the generator and starting-motor windings of which are connected to the same commutator. Installation is usually by means of a silent chain, as on the Hupp (1915 and earlier). The characteristics of this type of machine are such that when running at a speed equivalent to 9 miles per hour or less, it acts as a motor, and when the speed increases, it automatically becomes a generator and begins to charge the battery.

Regulation. The third-brush method of regulation is employed, the amount of current supplied to the shunt fields by this brush decreasing as the magnetic field of the generator becomes distorted owing to increased speed.

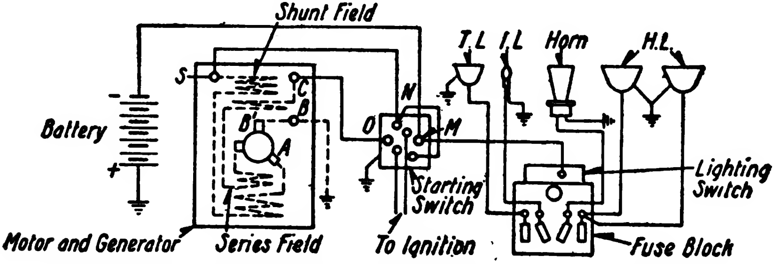


Fig. 359. Wiring Diagram for Westinghouse Single-Unit System on Hupmobile

Control. The switch employed with this type of combined unit is the regular single-throw single-pole switch used on lighting-plant switchboards. This switch controls both the ignition and the starting-motor circuits and, at starting, is thrown on and left closed as long as the car is running.

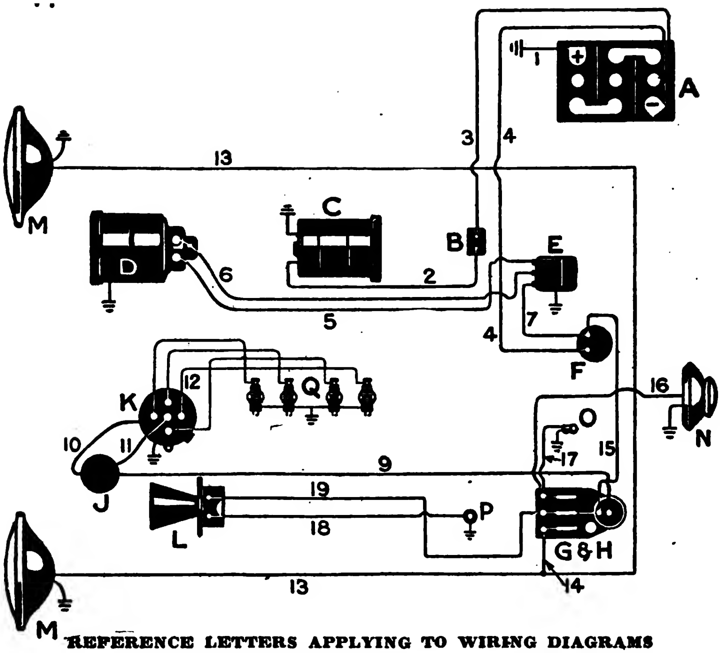
Wiring Diagram. The connections of the Hupp installation are shown in Fig. 359.

Instructions. *Battery Charging.* As the unit acts as a motor to drive the engine when the latter is running at a speed of less than the equivalent of 9 miles per hour on high gear, slow driving or permitting the engine to idle at a very low speed when the car is standing will discharge the battery. Where no fault in the wiring or connections exists and the battery will not stay charged (the generator, of course, working properly), this practice may be the cause of the trouble. If the voltage drops to 10 or 11 volts, with the headlights on but with the engine stopped, it indicates that the battery is practically discharged. This voltage reading will be somewhat higher in summer than in winter. The remedy is to run with fewer lights at night or to run the engine for longer periods in the daytime, or at higher speeds. Running solely at night will not keep the battery sufficiently charged, as most of the generator output is consumed by the lamps. Should the battery become discharged to a point where it cannot operate the starting motor, disconnect the wires *C* and *S* at the dynamotor, taping their terminals to prevent contact with any part of the engine or chassis. Start the engine by hand and, when running at a speed of about 500 r.p.m., reconnect these wires, *being sure to connect wire S first,* when the battery will begin to charge.

Fire Prevention. Gasoline or kerosene is frequently employed to wash automobile engines. Before doing so, be sure that the starting switch is open, and disconnect the negative terminal of the battery, taking care that it does not come in contact with any metal parts of the car. To make certain of this, it is better to tape the metal terminal. Allow the gasoline to evaporate entirely before reconnecting the battery, as a flash or spark would be liable to ignite the vapor. This naturally applies to all cars, although only such as are equipped with the Westinghouse single-unit or the Dyneto single-unit have starting switches which remain closed all the time the engine is running.

Weak Current. If the dynamotor fails to operate when the starting switch is closed, open the switch and test with the portable voltmeter. If it indicates less than 11 volts, the battery is run down; if it indicates 12 volts or over, look for a loose connection or an open circuit (broken wire) either in the connection from the battery to the starting switch, from the switch to the dynamotor, from the latter to the ground, or from the battery to the ground, in the order named. Dim burning of the lamps when the engine is stopped also indicates a discharged battery. When this is the case, it is advisable to recharge at once from an outside source, if possible.

A quick method of determining whether there is a ground in the wiring is to disconnect the battery wire and, the engine being stopped



REFERENCE LETTERS APPLYING TO WIRING DIAGRAMS

A—Storage Battery
B—Starting Switch
C—Starting Motor
D—Generator
E—Voltage Regulator
F—Ammeter
G—Ignition Switch
H—Lighting Switch
J—Spark Coil
K—Atwater-Kent Igniter
L—Horn
M—Head Lamps
N—Tail Lamp
O—Instrument Lamp
P—Horn Push Button
Q—Spark Plugs

Westinghouse Ignition, Starting, and Lighting Installation on Hupmobile Series N 1916-17 Cars. Upper Diagram Applies to Westinghouse Equipment for Numbers 60000 to 75000; Lower Diagram Applies to Cars after 75000

Courtesy of Hupp Motor Car Corporation, Detroit, Michigan

Westinghouse Ignition, Starting, and Lighting Installation on the Daniels Eight, 1917
Courtesy of Daniels Motor Car Company, Reading, Pennsylvania

and all lights turned off, touch the disconnected wire to the terminal lightly. A spark, when this contact is made, will indicate a ground between the battery and the dynamotor or the switch. The testing lamp should then be used to locate the circuit in which the ground exists.

Failure to charge properly may be due also to imperfect contact at the brushes or to a break in the shunt-field circuit of the generator, as explained in previous instructions. If the shunt-field circuit is found open, the trouble doubtless has been caused either by a ground between the battery and the generator or by running the generator when it was disconnected.

To remove the brushes, lift the spring that holds the brush in the guide and take out the screw holding the brush shunt, when the brush can be slipped out. Care should be taken to replace brushes in the same position, and if they do not bear evenly over their entire surface on the commutator, they should be sanded-in as described in the Delco instructions. The latter suggestion also applies to new brushes.

Fig. 360. Westinghouse Four-Pole Generator for Six-Volt Double-Unit Single-Wire System
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

Six-Volt; Double-Unit; Single-Wire

Generators. Four types of generators are made, as illustrated in Fig. 116, Part III; in Fig. 157, Part IV; and in Fig. 360, shown herewith, the fourth being similar to the unit shown on this page except for the method of regulation employed, which is of the third-brush type.

Regulation. The reverse series-field winding, or bucking-coil, method is used in the first two types of generator, while a voltage regulator combined with the battery cut-out is employed on the

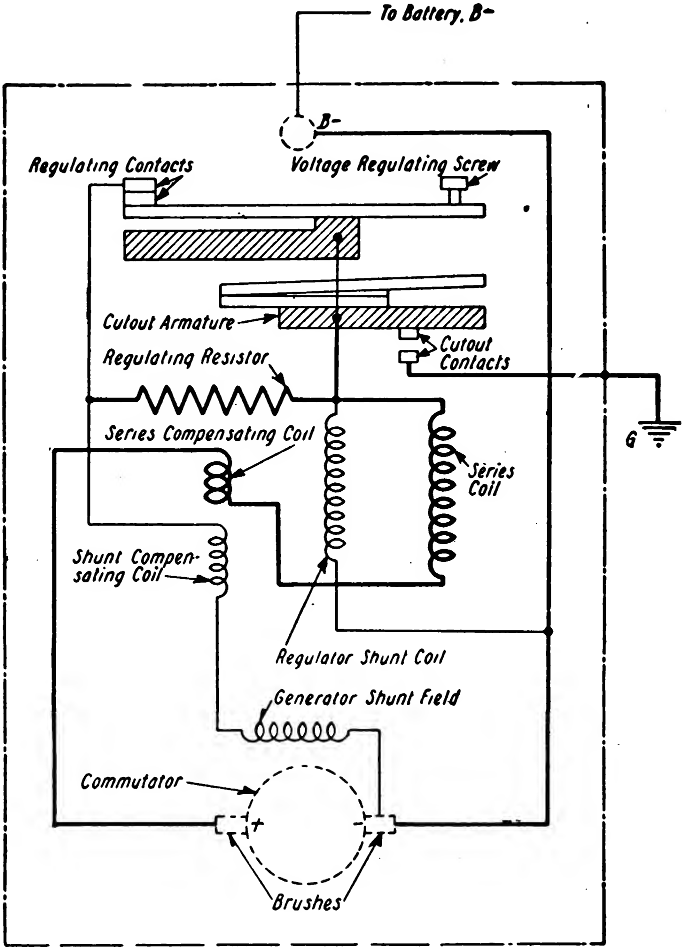


Fig. 361. Wiring Diagram for Westinghouse Generator with Self-Contained Regulator

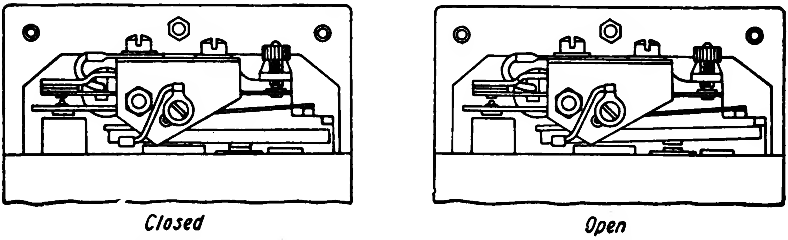


Fig. 362. Closed and Open Position of Westinghouse Cut-Out Switch

Fig. 363. Wiring Diagram for Westinghouse System with External Regulator

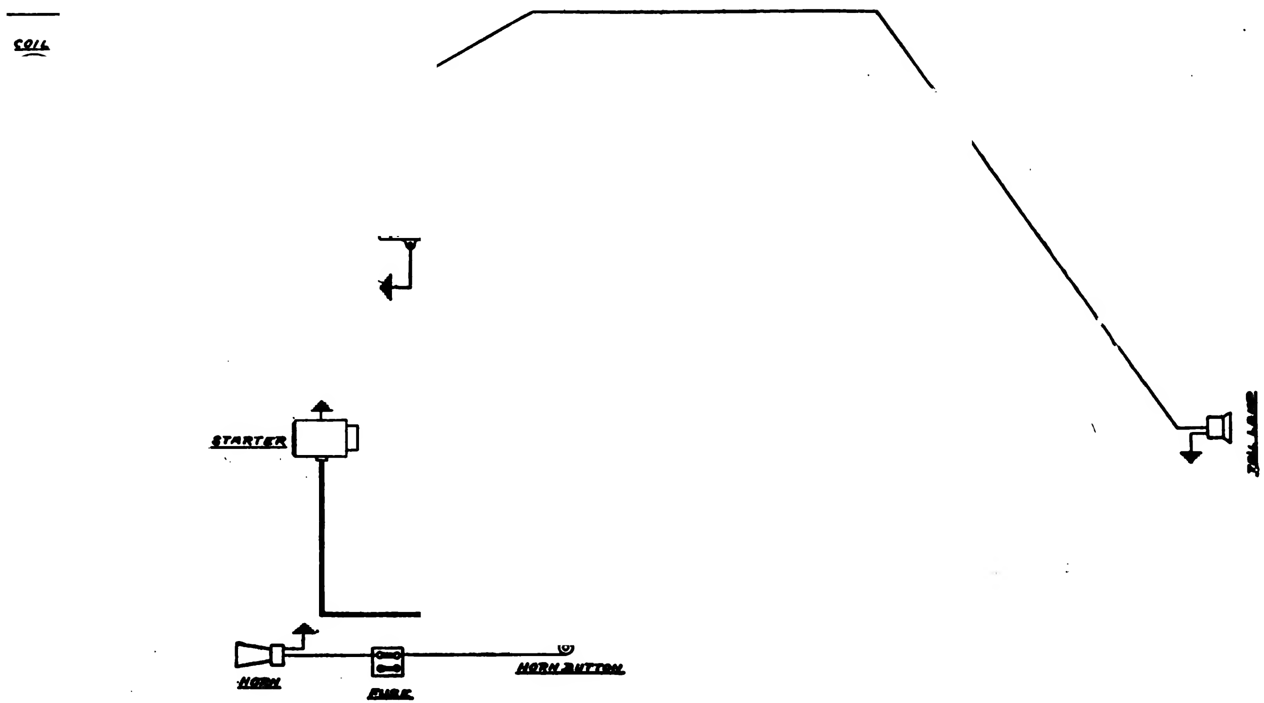
third, and the third-brush method on the fourth. This regulator is either self-contained, i.e., built in the generator, or is mounted independently. The connections of the built-in regulator are shown in Fig. 361. The open and closed positions of the contacts of the external cut-out are shown in Fig. 362.

Wiring Diagram. Fig. 363 shows the connections of the separately mounted regulator together with the charging and lighting circuits.

Fig. 364. Westinghouse Cut-Out Switch of Generator with Third-Brush Regulation

Battery Cut-Out. The type of automatic cut-out used with the type of generator employing the third-brush method of regulation is illustrated in Fig. 364. This may or may not be combined with a starting switch mounted on the engine side of the dash or some similar location. Fig. 365 is a wiring diagram showing the connections of the separately mounted cut-out with the third-brush generator. The cutting-in speed varies from five to ten miles per hour on high gear, varying with the gear ratio and wheel diameter of the car. This speed may be determined by running the car slowly and speeding up very gradually, meanwhile observing the increase in speed on the speedometer. The point at which the contacts close

Westinghouse Ignition, Starting, and Lighting Installation on the Cunningham Car, Model V
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania



Two-Brush Generator Wiring Diagram for Connecticut Ignition and Westinghouse Starter Installations on Dort 1916-17 Cars
Courtesy of The Dort Motor Car Company, Flint, Michigan

will be indicated by a slight quick movement of the ammeter needle. The cutting-out speed is slightly below this to prevent constant vibration of the cut-out armature when the car is being driven close to the cutting-in speed.

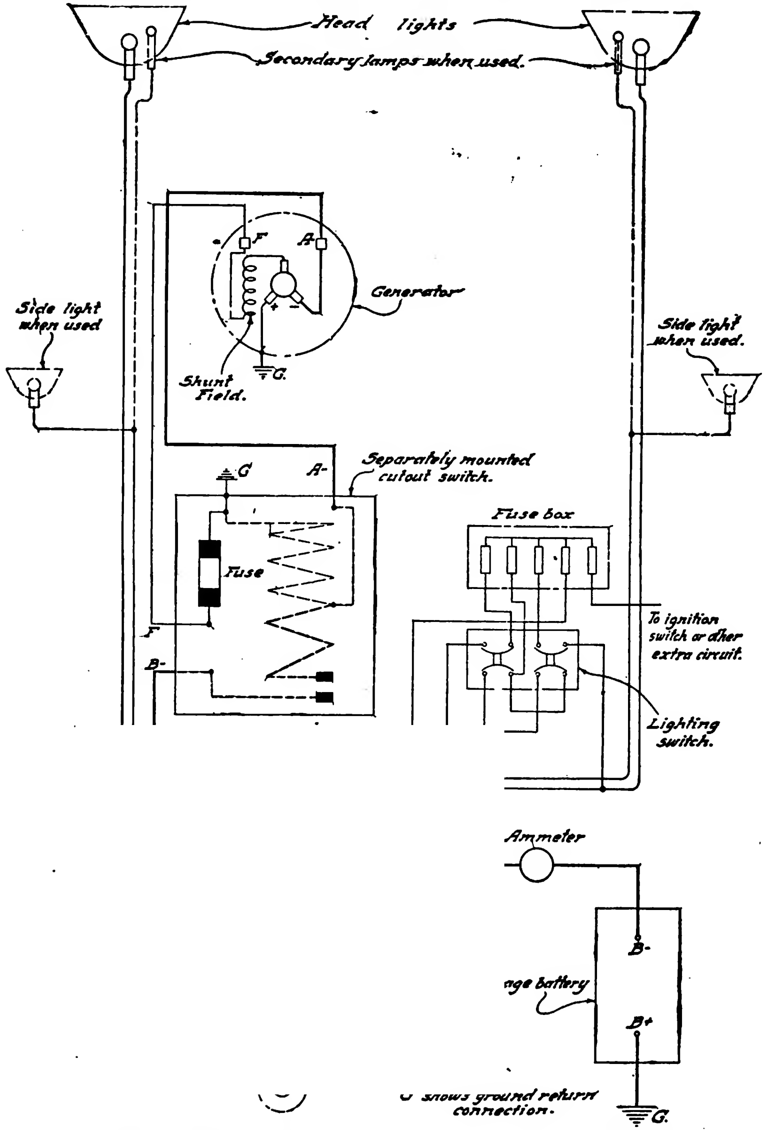


Fig. 365. Diagram of Connections for Complete Westinghouse System with Separately Mounted Regulator

Starting Motors. *Variations.* Several types are built to meet varying requirements; i.e., with self-contained reduction gearing, with single-reduction automatic screw pinion shift (Bendix drive), and with automatic electromagnetic pinion shift. The first two will be familiar from the descriptions already given of other makes. The third is similar in principle to the Bosch-Rushmore, but an independent magnet is employed instead of utilizing the armature of the motor itself for this purpose.

Magnetic Engaging Type. This type, as well as the other types of starting motors mentioned, may be operated either by a foot controlled switch or by a magnetically controlled switch put in action by a push button. The wiring diagrams, Fig. 366, show the circuits of both installations and also make clear the operation of the automatic engagement. The armature is mounted on a hollow shaft; and on the end of this shaft is carried a splined pinion designed to engage the flywheel gear. This pinion is caused to slide along the shaft by a shifting rod which is attached to the pinion and passes through the hollow shaft. The other end of this shifting rod acts as the core of the shifting magnet and will be recognized as the plunger of a solenoid. When the motor is idle, a spring holds the pinion at the right-hand end of the shaft and clear of the flywheel gear.

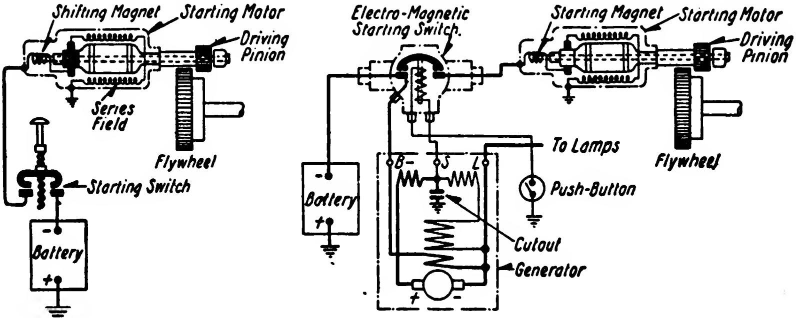
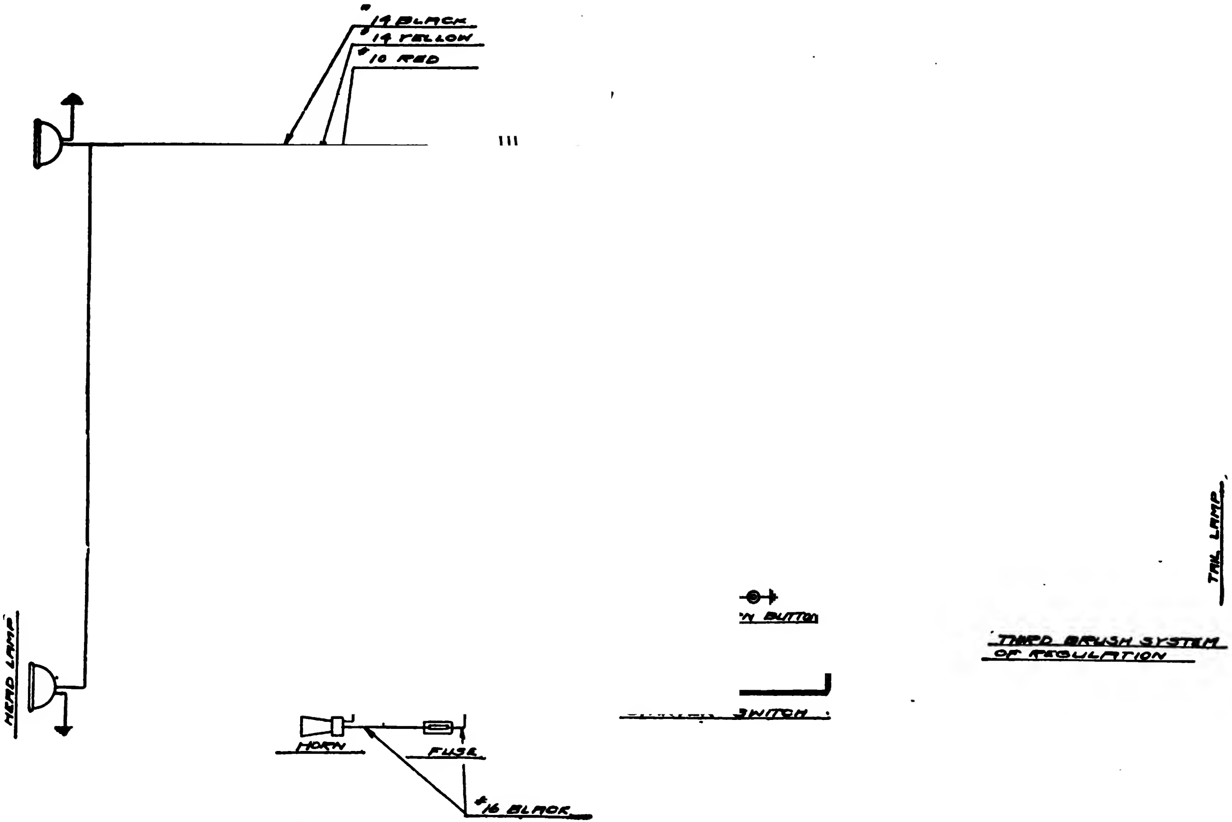


Fig. 366. Wiring Diagrams of Motor Connections for Automatic Electromagnetic Pinion Shift

As shown diagrammatically in Fig. 366, when the starting switch is closed, the circuit is completed from the negative terminal of the battery, through the switch, the shifting solenoid, the armature, and the series field of the motor to the frame of the car on which the positive side of the battery is grounded. The large amount of current necessary for starting energizes the shifting solenoid suffi-



Three-Brush Generator Wiring Diagram for Connecticut Ignition and Westinghouse Starter Installations on Dort 1916-17 Cars
Courtesy of The Dort Motor Car Company, Flint, Michigan

Westinghouse Ignition, Starting, and Lighting Installation with Double-Bulb Headlight on Allen 1916 Roadsters, Model 37.
Courtesy of The Allen Motor Company, Fostoria, Ohio

Delco Ignition and Westinghouse Starter Installations on National Highway Six, 1917-18
Courtesy of National Motor Car and Vehicle Corporation, Indianapolis, Indiana

Ground
ction

Switch

utton

d
st.

Autom

Motor

Dimmer

Bulb

Westinghouse Ignition, Starting, and Lighting Installation on Marion-Handley Six, 1917
Courtesy of The Mutual Motors Company, Jackson, Michigan

ciently to overcome the force of the spring so that it draws the shifting rod to the right through the hollow shaft, meshing the pinion with the flywheel gear. When the engine speeds up to the no-load speed of the starting motor, the current in the latter falls off so that the pull of the solenoid is less than that of the spring, and the pinion is automatically disengaged, though the motor will continue to revolve until the starting switch is opened.

Electromagnetic Switch. In principle, the electromagnetic switch is the same as that of the automatic engaging device for the pinion. The movable double-pole contact, instead of being attached to a rod for foot operation, is mounted on the plunger of a solenoid and normally is held open by a spring. This solenoid requires but a small amount of current for its operation and is connected on an independent circuit with the battery. It is controlled by a push button, and when the circuit is closed by means of the latter, the plunger of the solenoid is drawn into the coil against the pull of the spring, thus bringing the contacts together and holding them there as long as the solenoid is energized.

Instructions. *Regulator.* When the generator of the voltage-regulator type fails to charge the battery properly, all parts of the circuits and connections having been examined to determine that they are in proper condition, the regulator may be tested for faults. With the aid of the portable voltmeter, note at what voltage the contacts of the cut-out close or *cut in,* and at what voltage they *cut out* or open. See that the contact points are clean and square so that they make good contact over their entire surfaces when pressed together with the hand. Insufficient charging may be due to the voltage regulator keeping the voltage of the generator below the proper point for this purpose. A voltage adjusting screw is provided to compensate for this. With the voltmeter in circuit and the engine running, turn the screw very slowly and note the effect on the reading. For proper charging the latter should be approximately 7½ to 8 volts, and the screw should be adjusted very gradually to bring the voltmeter reading to this value. This screw is properly set at the factory and is unlikely to need adjustment; so all other possible causes should be investigated before changing it. The instructions for the 12-volt system also apply here, except that for voltage tests the system operates on 6 volts.

SPECIAL SYSTEMS FOR FORD CARS

FORD SYSTEM

General Instructions. On the latest model enclosed Ford cars such as the sedan and the coupé, an electric lighting and starting system is now being furnished as a regular part of the equipment. As will be noted by the illustration, Fig. 367, this has been designed especially for the Ford motor and is combined with it in a manner that makes it practically integral. The system is a standard two-unit six-volt single-wire type that is of conventional design throughout so that any repairman who is familiar with the other system previously described will at once recognize the layout of the Ford system and have no difficulty in handling it. The details of the generator and starting motor are shown in Fig. 368, while the complete wiring diagram is illustrated in Fig. 369. The battery is a 6-volt 13-plate Exide.

The precautions mentioned in connection with other systems of this type apply to the care and handling of the Ford. If for any reason the generator is disconnected from the battery, the engine must not be run unless the generator is grounded as otherwise it is apt to be burned out. A piece of wire, preferably flexible copper cable and in no case less than $\frac{1}{16}$-inch in diameter, should be run from the terminal on the generator to one of the valve cover stud nuts, making sure that the wire is tightly held at both ends.

Removal of Starting Motor. It is necessary to remove the starting motor to replace the transmission bands. To do this, first remove the engine pan on the left side of the engine and then take out the four small screws holding the shaft cover to the transmission cover. Upon removing the cover and gasket, turn the Bendix driveshaft around so that the set screw on the end of the shaft is in the position shown in the illustration, Fig. 368. Immediately under the set screw is placed a washer of the locking type, having lips or extensions oppositely placed on its circumference. One of these is turned against the collar and the other is turned up against the side of the screw head. Bend back the lip which has been forced against the screw and remove the set screw. A new lock washer of this type must be used when replacing the starting motor.

Pull the Bendix assembly out of the housing, taking care to see that the small key is not lost. Remove the four screws which hold the starter housing to the transmission cover and pull out the starting motor, taking it down through the chassis, which explains

Fig. 367. Top View of Model T Motor, Showing Starter and Generator in Position

Courtesy of Ford Motor Company, Detroit, Michigan

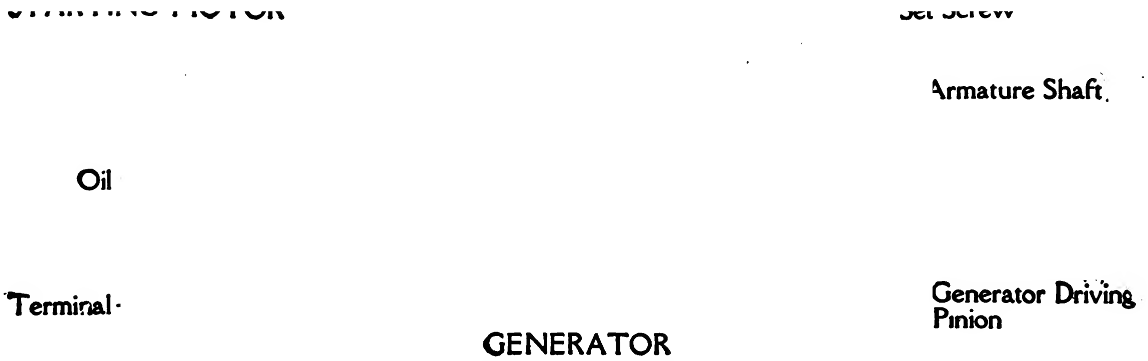


Fig. 368. Starter and Generator Units
Courtesy of Ford Motor Company, Detroit, Michigan

Fig. 369. Wiring Diagram Sedans and Coupes

Courtesy of Ford Motor Company, Detroit, Michigan

the reason for removing the engine pan. In replacing the starting motor, note that the terminal for the electric cable must be placed on top. If the motor is placed in any other position, the cable will not reach to the terminal. In case it is necessary to run the car without the starting motor in place, transmission cover plates supplied for the purpose should be put in place to exclude dirt and prevent the waste of oil.

Removing Generator. To take the generator off the engine, first take out the three cap screws holding it to the front end cover and by placing the point of a screw driver between the generator and the front end cover, the generator may be forced off the engine assembly. Always start at the top of the generator and force it backward and downward at the same time. In case it is necessary to run the car without the generator in place, a plate may be had to cover the opening thus left in the timing gear case. Should the battery be removed, the engine must not be run without grounding the generator in the manner already explained.

The generator is driven from the large timing gear to which the camshaft is attached and is set to cut into the battery circuit when the speed of the motor is equivalent to 10 miles an hour on the direct drive, while it reaches its maximum at 20 miles per hour. Both the generator and the starting motor are lubricated by the splash system of the engine itself, but an additional oil cup is placed on the rear end bearing of the generator and should be given a few drops of oil at short intervals.

Lighting and Ignition. The lighting system consists of two double-bulb headlights and a small taillight controlled by a combination lighting and ignition switch mounted on the instrument board and the connections of which will be noted in the wiring diagram. All of the lamps are connected in parallel, current being supplied for them by the battery. The lamps should never be connected to the magneto, as the higher voltage of the latter will burn out the bulbs and it may discharge the magnets.

Reference to the wiring diagram will show the connection between the battery and the combination lighting and ignition switch by means of which the battery current may be sent through the induction coils for starting. On models equipped with starting and lighting systems, the magneto is employed solely for ignition. Whenever any adjustments or repairs are to be made to the wiring, the cable leading to the positive side of the battery should first be disconnected and protected with insulating tape. Otherwise, the battery current is apt to be passed through the magnet coils, and this will result in discharging the magnets.

The operation of the system is checked by means of an ammeter mounted on the instrument board. When the lights are burning and the engine is not running at a speed in excess of the equivalent of 10 miles an hour, the ammeter will show *discharge*. At a speed of 15 miles per hour or faster, the ammeter should show a reading of 10 to 12 amperes, even with the lights burning. When the ammeter fails to give a *charge* reading with the engine running at a speed of 15 miles an hour or better, the generator should be tested, if an examination fails to reveal any loose connections at the ammeter or on its line. To make the generator test, the cable is disconnected from its terminal on the generator and the engine run at a moderate speed. With a pair of pliers, short-circuit the generator by placing against the terminal stud and against the housing of the generator at the same time. If the generator is in good working condition, a bright spark will result. The engine should at once be stopped, as the generator should not be run in this condition a moment longer than necessary. An inspection of the connections and wiring as outlined in previous sections will be found equally effective in discovering short-circuits or grounds as in any of the other systems mentioned.

Operating Starter. The management of the starter is simple. The spark and throttle levers should be placed in the same position on the quadrant as when cranking by hand, and the ignition switch turned on. Current from either battery or magneto may be used for ignition. When starting, especially if the engine is cold, the ignition switch should be turned to "battery." As soon as the engine is warmed up, turn switch back to "magneto." The starting motor is operated by a push button, conveniently located in the floor of the car at the driver's feet. With the spark and throttle levers in the proper position, and the ignition switch turned on, press on the push button with the foot. This closes the circuit between the battery and starting motor, causing the pinion of the

Bendix drive shaft to engage with the teeth on the flywheel, thus turning over the crankshaft. When the engine is cold, it may be necessary to prime it by pulling out the carburetor priming rod, which is located on the instrument board. In order to avoid flooding the engine with an over-rich mixture of gas, the priming rod should only be held out for a few seconds at a time.

GRAY AND DAVIS

General Instructions. Gray and Davis and some of the other leading manufacturers who make the starting and lighting equipment for larger cars also manufacture a special type designed for the Ford. These special Ford systems are simple and compact, and everything necessary to install them on the machine is provided by the maker of the apparatus so that they may be installed, either by the owner of the machine or by the local garage man whose electrical experience is limited. This necessitates the removal of the radiator, radiator brace rod, hose connections, fan, fan pulleys and belt, cylinder head, and in some cases the timing-gear housing. The ground connection of the headlights, which is soldered to the back of the radiator on 1915 and subsequent models provided with electric headlights supplied by the Ford magneto, must be discarded altogether, as the lights are to be supplied by the storage battery. In cases where it is necessary to remove the timer (this must be done when the timing-gear housing has to be removed), both the timer and the carburetor should be adjusted for efficient running before starting to dismantle the engine, and if the latter is turned over while the timer is off, the ignition timing must be readjusted when the timer is put back. As the removal of all the parts mentioned is a simple matter fully covered in the Ford instruction books and familiar to practically every garage man in the country, they are not repeated here.

Installation. *Preparing Engine.* Remove the radiator, disconnecting the ground wire from it; disconnect the wires from the head lamps and remove the head lamps and supports. Take off the bracket and fan, Fig. 370, and turn the engine by hand until the pin *2* in the fan pulley is straight up and down; remove the pin from the jaw clutch and remove the starting-crank *4*, belt *5*, and the cotter pin, *3;* take the pin from the fan pulley and remove the pulley *6*. Remove the second, fourth, and fifth bolts from the crankcase flange *7*, the left and front bolt from the side-water connections *8* and *9*, as well as the second cylinder-head bolt *10*.

NOTE—The numerals refer to the parts to be removed or replaced, as well as the sequence in which the operations are to be carried out, as shown on the sketches. Each illustration, however, has its own series of the same numbers, which should not be confused with those on other views.

Lay the chain *1* in the rear of the engine support around the crank-shaft, Fig. 371, and then place the original starting-crank jaw clutch *2* inside of the crankshaft sprocket. Place the crankshaft sprocket *3* on the crankshaft and put the new belt *4* around the pulley on the crankshaft. Secure the sprocket with the new pin *5* (supplied) and then connect the starting crank in its original position. Secure the jaw clutch to the starting crank with pin *7*.

Fig. 370. Preparing Engine for Mounting Starting Unit
Courtesy of Gray & Davis, Boston, Massachusetts

Mounting Starter-Generator. In Fig. 372 is shown the starter-generator unit, for which note the following instructions: See that

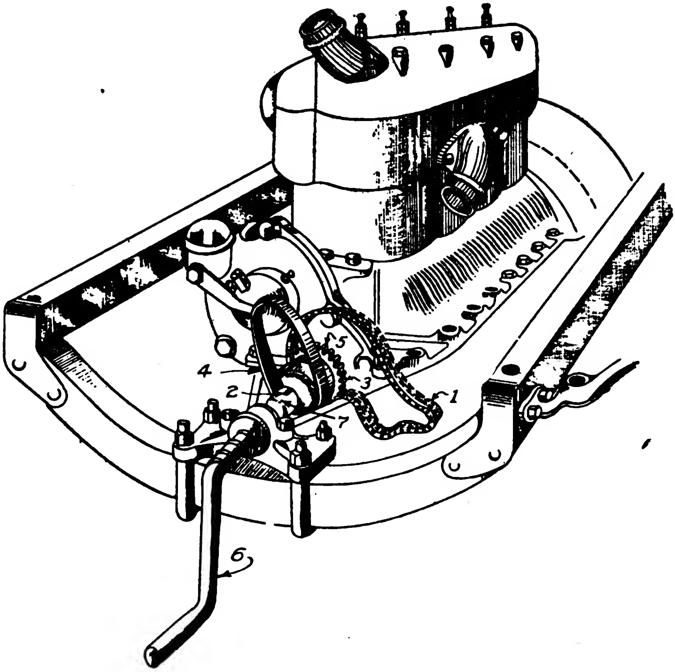


Fig. 371. Putting Driving Chain on Crankshaft Sprocket in Gray & Davis Ford Installation

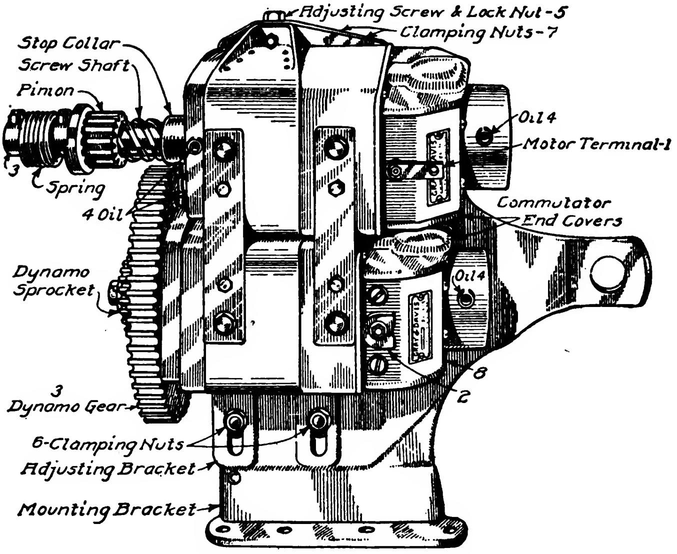


Fig. 372. Details of Gray & Davis Generator Unit for Ford Starter

the motor terminal *1* is free from contact with any other metal; also that the dynamo terminal *2* and insulation are not injured. Test the shaft and gears *3* to see that they turn freely, and then fill the oil cups *4* with oil.

Release the top adjusting screw *5*, also two lower clamping lock nuts *6* (front), as well as the two upper clamping lock nuts *7* (rear) and the single middle clamping lock nut *8* (front). The units must be in the lowest position possible on the bracket before placing it on the car. In Fig. 373 is shown the starter-generator unit in place on the engine with the bolts and nuts all tightened. This is carried out as follows:

Fig. 373. Starter Unit Mounted on the Engine
Courtesy of Gray & Davis, Boston, Massachusetts

Place three $\frac{3}{8}$-inch spacers over the first, second, and third holes in the crankcase flange *1*, and then place the unit on car *2;* pass three $\frac{3}{8}$- by $2\frac{1}{8}$-inch bolts through the lower bracket, but do not attach nuts *3*. Tip the starter unit forward and pass the chain over the dynamo sprocket *4;* attach the bracket by meams of cylinder-head bolt, but do not fasten.

Place a $\frac{13}{32}$-inch spacer between the bracket and top water connection *7* and attach the bracket with $\frac{7}{16}$- by $2\frac{5}{8}$-inch bolts, but do not fasten securely; then place $\frac{1}{32}$-inch spacers *7A* under the bracket so that the chain will be tight when the units are in the lowest possible position. Use washers *8* as shims between the bracket and the cylinder-head link. Secure the three lower bracket bolts *9* with lock washers and nuts, also secure the water-connection bolts *6* and *7* and the cylinder-head bolt *5*. Adjust the bracket stay bolt *10*, adjust the chain *11* to moderate the tension and lock adjustment, securely tighten five clamping bracket nuts, and then crank the engine slowly by hand to see that everything turns smoothly. If, through some irregularity in the engine casting the bracket should not seat properly, it may be necessary to file the bracket holes to meet this condition. Be sure that the sprockets are in true alignment, or the uneven strain may cause injury. If necessary, elongate the holes in the bracket or shim bracket as needed to insure perfect alignment of chain.

Fig. 374. Installing Gray & Davis Wiring and Lighting Switch on Ford Car

When adjusting the bracket stay bolt *10*, make sure that it rests against the engine casting without strain and secure it with nuts on each side of the bracket. Bend the ignition timing to clear the chain, if necessary, but after bending, the distance between the ends of the rod in a straight line must be equal to its original length. Adjust the chain to moderate tension and secure both the adjustment lock nuts at the top. If all five nuts holding the adjustable bracket are not released before adjusting, uneven strain may cause injury. Securely tighten the sliding-bracket nuts *12*—two at the bottom front side, two at the top rear, and one at the front end. Test by turning the engine over by hand slowly.

Remounting Engine Parts. Fit split pulley *1* to the hub of the fan, Fig. 374, and attach split pulley *2* with four screws; slip a new belt over the fan pulley, attach the fan, and adjust. Place the radiator *4* on its support and screw the radiator rod into the radiator and secure with check nut *3;* secure the hose clamps at the top and side water connection *6;* place the radiator nuts and secure with cotter pins. Attach the lighting switch at the cowl (left) with $\frac{3}{16}$-inch screws and attach three lighting-cable clips on the rear of the dash, using $\frac{1}{2}$-inch wood screws; cut the corner from the toe board for clearance. Attach three wire clips *10* to the left side of the frame and attach green wire *11* to the dynamo terminal. Then connect the short black and red wire to the left head lamp. Pass a long black and red wire through the radiator tube to the right head lamp, then connect the short wire from each head lamp to the metal of the car frame *14*. Attach the starting cable *15*, which has a copper terminal at each end, to the starting-motor terminal. Refill the radiator and watch carefully for leaks in the circulation system.

Fig. 375. Installation of Starting Switch
Courtesy of Gray & Davis, Boston, Massachusetts

Starting Switch. The location of the starting switch and the method of installing it are shown in Fig. 375. Take the plate *1* off the starting switch and use it to mark the holes in the floor strip two inches in front of heel board and nine inches from the sill, as shown in the illustration. Make three holes for the starting switch in the rear floor strip *2* and attach the switch with bolt *3* at the side nearest the center of the car; then attach the other switch bolt *4*, support the cable clip holding the two wires, and secure the spring and the knob with a pin.

Priming Device. Connect the priming device *1*, Fig. 376. Drill a $\frac{7}{32}$-inch hole in the dash two inches to the right of the coil box and six inches above the toe board and pass the upper rod through. Connect the lever arm *2* vertically to the foremost exhaust manifold bolt with stationary member in horizontal position; then connect the lower rod *3* to the carburetor priming lever. Work it back and forth several times to make sure that it returns to normal position when released.

Battery. Place the battery box on the right-hand running board, Fig. 377, to permit easy opening of doors and access to battery box; then mark four holes with the center punch. Drill four holes $\frac{11}{32}$ inch in diameter in the running board *2*, using a jack or prop to support the running board while drilling. Replace the battery box on the running board in order to mark the holes in mud guard for insulating cable bushings *3*, then make two holes $1\frac{3}{8}$ inches in diameter. Insert insulating-cable bushing *4* in left hole and secure with round wooden nut; do the same with the right-hand bushing *5*. Secure wood nuts *6* with a wire twisted around the thread. A coat of heavy paint will also hold the nut in place and preserve the insulator. Place the two flat wood cleats *7* with holes at each end between the battery box and the running board; then pass four bolts *8*, $\frac{3}{8}$ inch by $1\frac{1}{2}$ inches, through

Fig. 376. Replacement of Carburetor Timing Rod on Dash
Courtesy of Gray & Davis, Boston, Massachusetts

the battery box, cleats, and running board, and secure them with four nuts and lock washers. Place two special-shaped wood cleats *9* inside the battery box, one at each end for the battery to rest upon, so that holes in the cleats will fit over the bolt heads. Raise springs *10* and hang on the side of the battery box, placing the battery in the box and inserting two ½-inch wood strips, one each side between the battery and the battery box. Attach two springs *11* at opposite ends

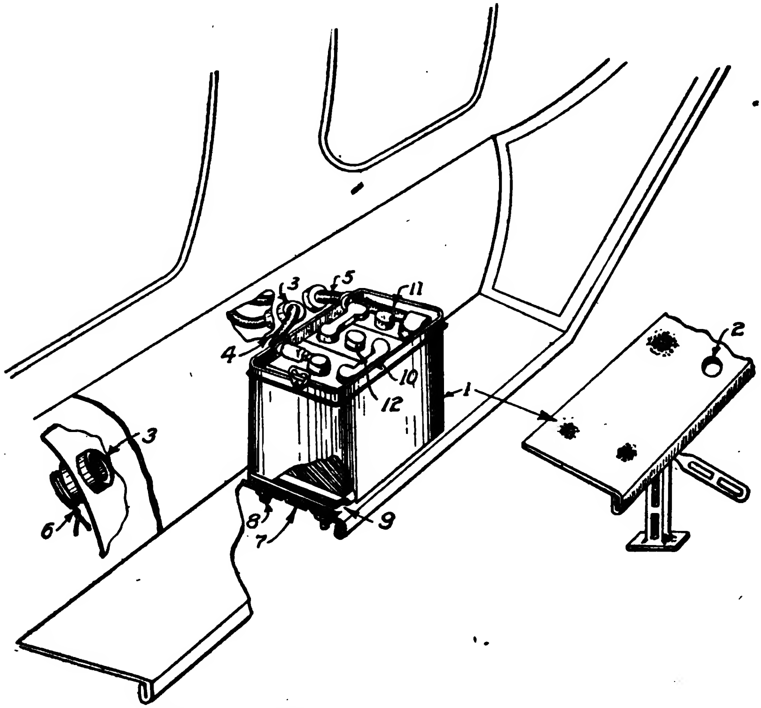


Fig. 377. Installing Gray & Davis Battery and Wiring

to hold the battery down securely. Inspect the battery and if the solution does not cover the plates at least ¼ inch, add pure water, filling the cells to ⅝ inch above the tops of the plates. Water for battery use should be free from iron or alkali.

Final Connections and Adjustments. Fig. 378 is a plan view of the chassis, showing the entire system in place. Figs. 379 and 380 show the wiring in plan and in perspective. Drill and attach to the woodwork on the underside of the body *1* three wire clips holding the

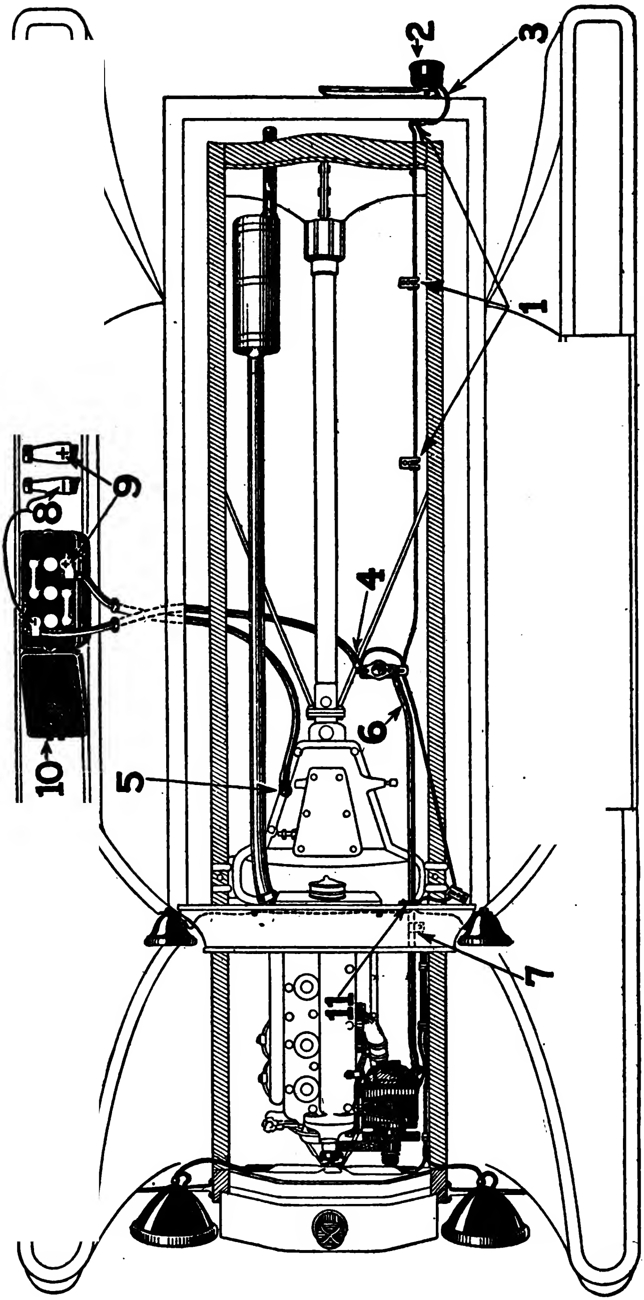
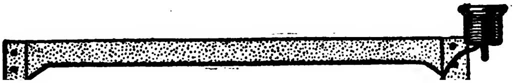


Fig. 378. Plan View of Complete Wiring System for Gray & Davis Ford Installation
Courtesy of Gray & Davis, Boston, Massachusetts

tail-light wire; see that the wire does not make contact with any metal edges. Attach the electric light *2*. If the tail lamp has a one-point wire connector, the lamp body must be metallically connected with the chassis frame. Be sure the connecting surfaces are clean, free from paint, and securely connected. Connect the tail-light wire *3* to the tail lamp. Tail lamps are usually made with a single wire connector, but, if the lamp has two wire connectors, another wire



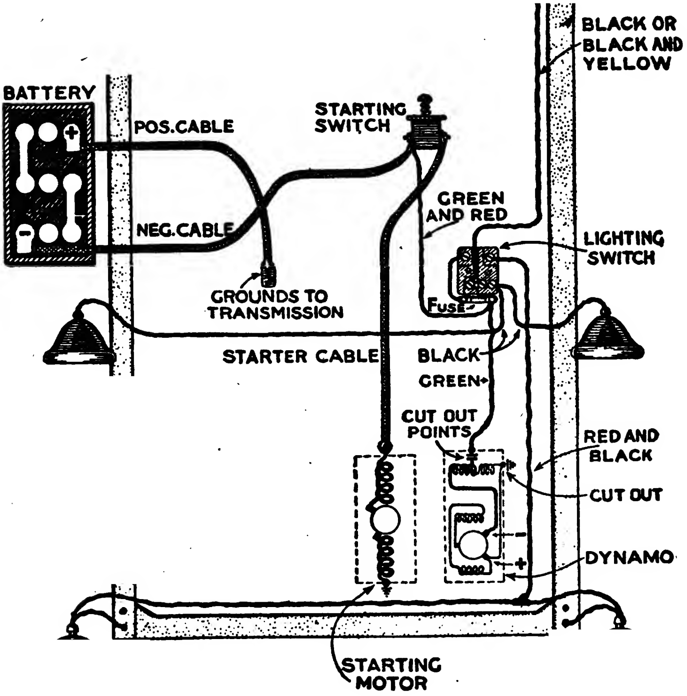


Fig. 379. View of Complete Wiring System Simplified

should run from the second terminal of the connector to the metal framework of the car. Connect the short starting cable *4* (negative) and the green and red wire to the starting-switch terminal nearest the battery. Then pass the end of the battery cable through the foremost insulator in the mud guard. Attach the end of the starting cable *5*, leading through the rear hole in the mud guard, to the second bolt in the transmission case. Use a lock washer and a plain washer under the head of the bolt to insure permanent contact. This is the positive cable which connects to the + terminal *9* of the battery. Then pass the end of the cable through the rear insulator in the mud guard and under the exhaust pipe, which it must not touch. Attach to the starting-switch terminal *6*, securely, the end of the cable which runs to the starter. Support the starter cable *7* by a clip to the inside curved edge of the dash. When connecting cables to the battery, be sure that the terminals are securely fastened—firm contact must be made. The battery terminals are made of lead and must be handled carefully. Battery-cable terminals

Fig. 380. Pictorial View of Wiring Diagram for Gray & Davis Ford Installation

differ slightly in size and correspond to the holes in the battery terminal, the negative-cable terminal being the smaller. Pass the foremost cables *8* through the battery-box insulator and connect them firmly to the negative battery terminal. Do not connect the positive cable to the battery or insert the fuses until the installation has been made in accordance with the instructions and tests show that wires are not in contact with the frame of the car. Turn the lighting switch off and touch the positive terminal lightly to the battery terminal. If there is a spark, it indicates a short-circuit or a ground, caused by a wire coming in contact with the frame. Remedy the trouble before connecting up the battery. If there is no spark, permanent connection may be made. The lamp-test set may be used to determine whether there are any grounds or short-circuits, before connecting up the battery.

When all indications show that the installation has been made properly, connect the positive starting cable to the positive terminal *9* of the battery. Place and secure the cover *10* on the battery box. Place fuse *11* in fuse clip of lighting switch. Fig. 381 shows details of the different types of lamps.

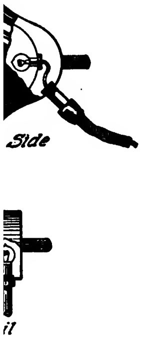


Fig. 381. Details of Gray & Davis Ford Lamps

Instructions. Oil the two generator bearings and the two motor bearings every 200 miles, keeping oil-well covers closed. The chain must be kept well adjusted. When the unit is first installed or when a new chain has been fitted, the chain should be adjusted occasionally during the first 500 miles of travel until all stretch has been taken out of it. After this distance has been run, the chain stretch will be slight. Never allow the chain to run slack.

To adjust the chain, release five clamping nuts (2 nuts in the rear of the bracket at the top, 2 in front of the bracket at the bottom, and 1 at the right-hand side) a few turns to permit the bracket to slide. Then adjust the chain to moderate tension by turning the adjusting screw at the top of the bracket and tighten the check nut and adjusting screw to lock the adjustment. Then retighten all five clamping nuts securely. Turn the engine by hand to determine whether the chain runs smoothly; the chain should not be too tight. After long service, when all chain adjustment has been taken up, the chain may be shortened by taking out a pair of links. The latest type of chain is supplied with a removable pair of links, retained in position by two removable pins. These pins are a trifle longer than the regular riveted pins.

Where the chain has been shortened, it is sometimes necessary to lower the supporting bracket slightly by removing some of the $\frac{1}{32}$-inch washers under the bracket or by filing the spacers slightly, so that the chain will be tight when the unit is in the lowest possible position.

Wires are subject to dislodgement and injury, hence they should be examined carefully to see that they are not resting on sharp edges of metal and that the insulation is not worn or injured. See that none of the wires are swinging or rubbing against metal, as this is likely to injure the insulation. Also examine the cables leading through the battery box and mud guards; the bushings must be intact and in place to protect the cables from short-circuiting. Wherever injury to any part of the insulation is found, wrap the spot carefully with insulating tape and bend away from the metal to provide sufficient clearance to prevent further damage.

If the lamps fail to light when the lighting switch is operated, the fuse on the back of the lighting switch should be examined; it may be burned out, broken, or not properly clamped in its fuse clips. The wires may not be properly connected (this should be checked by wiring diagram), the bulbs may be burned out, or the filaments may be broken. The lamp wiring may be short-circuited or the charging circuit may be open.

Do not run the engine with the battery disconnected or off the car without first insulating or removing two of the generator brushes to prevent the generator from generating a current. To determine if generator is operating properly, turn on the head and tail lamps while the engine is idle. Start the engine and accelerate to charging speed or over; a perceptible brightening of the lamps will indicate that the machine is generating sufficient current both to charge the

PLATE 81—JORDAN WIRING DIAGRAM OF 1920 MODEL F, DELCO SYSTEM

PLATE 82—JORDAN WIRING DIAGRAM OF 1920 MODEL F, SERIES 2, DELCO SYSTEM

PLATE 83—JORDAN WIRING DIAGRAM OF 1920 MODEL M, DELCO SYSTEM

PLATE 84—KING WIRING DIAGRAM OF 1915 MODELS C, D, WARD LEONARD SYSTEM

PLATE 85—KING WIRING DIAGRAM OF 1916 MODELS D, E, WARD LEONARD SYSTEM

PLATE 86—KING WIRING DIAGRAM OF 1917-18 MODELS EE, F, BIJUR SYSTEM

PLATE 87—KING WIRING DIAGRAM OF 1920 MODEL H, WESTINGHOUSE SYSTEM

PLATE 86—KISSEL WIRING DIAGRAM FOR 1915 MODEL 4-36, WESTINGHOUSE SYSTEM

PLATE 89—KISSEL WIRING DIAGRAM FOR 1915 MODEL 6-42, WESTINGHOUSE SYSTEM

PLATE 90—KISSEL WIRING DIAGRAM FOR 1916 MODELS 4-32, 4-36, WESTINGHOUSE SYSTEM

PLATE 91—KISSEL WIRING DIAGRAM FOR 1917 ONE HUNDRED POINT SIX, WESTINGHOUSE SYSTEM

PLATE 92—KISSEL WIRING DIAGRAM FOR 1918 ONE HUNDRED POINT SIX, REMY SYSTEM

PLATE 93—KLINE WIRING DIAGRAM FOR 1916 MODEL 6-36, WESTINGHOUSE SYSTEM

PLATE 94—LAFAYETTE WIRING DIAGRAM OF 1920 EIGHT-CYLINDER MODEL, DELCO SYSTEM

PLATE 96—LEXINGTON WIRING DIAGRAM OF 1920 MODEL S, GRAY & DAVIS STARTING AND LIGHTING, CONNECTICUT IGNITION SYSTEMS

PLATE 96—LIBERTY WIRING DIAGRAM OF 1919-20 MODELS 10-B, 10-C, WAGNER SYSTEM

battery and to light the lamps. Do not open the charging circuit at any time when the engine is running.

Testing Generator with Ammeter. A more accurate determination may be made by connecting an ammeter in the circuit. Disconnect the red and green wire connected to the fuse terminal on the back of the lighting switch and connect it to one terminal of the ammeter. From the other terminal of the ammeter, connect a wire to the fuse terminal to which the red and green wire was previously connected. Turn the lights on with the engine idle. The ammeter should register "discharge", the reading representing the amount consumed by the lamps turned on, i.e., head and tail lamps, 5 to 6 amperes; side and tail lamps, 1½ to 2 amperes. If the ammeter indicated "charge" instead of "discharge", with the lamps turned on and the engine idle, reverse the wires connected to the ammeter terminals. In case the ammeter does not register, see that the pointer is not jammed, otherwise, the circuit is open at some point or the battery is exhausted.

Run the engine at a speed corresponding to 12 to 15 miles per hour, the lights being turned off. If the ammeter registers "charge", the generator is then charging the battery. Increase the engine speed to a car speed corresponding to 13 to 18 miles per hour. The ammeter reading should then be from 12 to 15 amperes. As the engine speed is increased above 18 miles per hour, the charging rate will decrease gradually to approximately 10 amperes at very high speed. With the engine running at 12 miles an hour or faster, turn the lights on; the charging rate should drop according to the number and size of the lamps turned on (see current consumed by each lamp as given above). Turn the lights off and, while permitting the engine to slow down, observe the ammeter. It should drop to zero at approximately 0- to 2-ampere charge.

DELCO IGNITION AND BIJUR STARTING AND LIGHTING INSTALLATION ON PACKARD "TWIN SIXES", SERIES 3

Courtesy of Packard Motor Car Company, Detroit, Michigan

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VII

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

STARTING AND LIGHTING STORAGE BATTERIES

Importance of the Battery in Starting and Lighting. In the last analysis, every electric lighting and starting system on the automobile is necessarily a battery system. An electric starter is, first and last, a battery starter, since no system can be any more powerful than its source of energy. In other words, the storage battery is the business end of every electrical starting and lighting system. Just as the most elaborate and reliable ignition apparatus is of doubtful value with poor spark plugs, so the finest generators, motors, and auxiliaries become useless if the battery is not in proper working order.

Storage Battery Requires Careful Attention. A little experience in the maintenance of electric starting and lighting systems will demonstrate very forcibly that the relative importance of the storage battery is totally disproportionate to that of all the remaining elements of the system put together. The latter essentials have been perfected to a point where they will operate efficiently without attention for long periods. The battery, on the other hand, requires a certain amount of attention at regular and comparatively short intervals. Usually, this attention is not forthcoming, or it may be applied at irregular intervals and with but scant knowledge of the underlying reasons that make it necessary. Consequently, the battery suffers. It is abused more than any other single part of the entire system and, not being so constituted that it can withstand the effects of this abuse and still operate efficiently, it suffers correspondingly. Then the entire system is condemned.

Other things being equal, the successful operation of any starting and lighting system centers almost wholly in the proper maintenance of the storage battery. Not all the defections that this part of the electrical equipment of the car suffers are caused by the battery, but unless properly cared for, it will be responsible for such a large proportion that the shortcomings of the rest of the system will be entirely forgotten. To make it even stronger, it may well be said that unless the storage battery is kept in good condition, the rest of the system will not have an opportunity to run long enough to suffer from wear. In a great many cases that come to the repair man's attention, the battery is ruined in the first six months' service, usually through neglect. For this reason, considerable attention is devoted to the battery and its care in this connection, despite the fact that it is very fully covered in the volume on Electric Vehicles. The conditions of operation, however, are totally unlike in the two cases. In one instance, the energy of the battery is called for only at a rate of discharge which is moderate by comparison with the ampere-hour capacity, while the battery itself is constantly under the care of a skilled attendant. In the other instance, the demand for current is not alone excessive but wholly disproportionate to the total capacity of the battery when it is used for starting, and intelligent care is usually conspicuous by its absence.

PRINCIPLES AND CONSTRUCTION

Function of Storage Battery. In the sense in which it is commonly understood, a battery does not actually store a charge of electricity. The process is entirely one of chemical action and reaction. A battery is divided into units termed *cells*. Each cell is complete in itself and is uniform with every other cell in the battery, and one of the chief objects of the care outlined subsequently is to maintain this uniformity. Each cell consists of certain elements which, when a current of electricity of a given value is sent through them in one direction for a certain length of time, will produce a current of electricity in the opposite direction if the terminals of the battery are connected to a motor, lamps, or other resistance. The cell will, of course, also produce a current if its terminals are simply brought together without any outside resistance. This, however, would represent a *dead short-circuit* and would permit the battery to discharge itself so rapidly as to ruin its elements. This is one of the things that must be carefully guarded against. When attending a battery, see that its terminals are not left exposed where tools may accidentally drop on them. When the current is being sent into the battery, as mentioned above, it is said to be charging; when it is connected to an outside resistance, it is discharging.

Parts of Cell. *Elements.* These are known as the positive and negative plates and correspond to the positive and negative electrodes of a primary battery. They consist of a foundation composed of a casting of metallic lead in the form of a grid, the outer edges and the connecting lug being of solid lead, while the remainder of the grid is like two sections of lattice work so placed that the openings do not correspond. Every manufacturer has different patterns of grids, but this description will apply equally well to all of them. Fig. 382 illustrates the grid of the Philadelphia battery. The object in giving them this form is to make the active material of the plates most accessible to the electrolyte, or solution, of the battery, and at the same time to insure retaining this active material between the sides of the grid.

Fig. 382. Lead Grid Ready for Active Material
Courtesy of Philadelphia Storage Battery Company, Philadelphia, Pennsylvania

This active material consists of peroxide of lead (red lead) in the positive plate and litharge, or spongy metallic lead, in the negative plate. The plates are said to be pasted, to distinguish them from the old-style plates which were "formed" by a number of charges and discharges. The active material is forced into the interstices of the grid under heavy pressure, so that when completed the plate is as hard and smooth as a piece of planed oak plank. The positive plate may be distinguished by its reddish color, while the negative is a dark gray. Each positive plate faces a negative in the cell, and as the capacity of the cell is determined by the area of the positive plates, there is always one more negative plate than positive plates in a cell. The lead connectors of each of the plates is burned to its neighbor of the same kind, thus forming the positive and negative groups which constitute the elements of the cell.

Separators. As the elements must not be allowed to come in contact with each other in the cell because to do so would cause an internal short-circuit to which reference is made later, and as the maximum capacity must be obtained in the minimum space, the plates are placed very close together with wood and perforated hard rubber separators between them. These are designed to fit very snugly, so that the combined group of positive and negative plates is a very compact unit. When reassembling a cell, it is important that these separators be properly cared for in accordance with the directions given later.

Electrolyte. To complete the cell, the grouped elements with their separators are immersed in a jar holding the electrolyte. This is a solution consisting of water and sulphuric acid in certain proportions, both the acid and the water being chemically pure to a certain standard. This is the grade of acid sold by manufacturers as battery acid and in drug stores as C.P. (chemically pure), while the water should be either distilled, be cleanly caught rain water, or melted artificial ice. In this connection, the expression "chemically pure" acid is sometimes erroneously used simply to indicate acid of full strength, i.e., undiluted, or before adding water to make the electrolyte. It will be apparent that whether at its original strength or diluted with distilled water, it is still chemically pure. In mixing electrolyte, a glass, porcelain, or earthenware vessel must be used and *the acid must always be poured into the water.* Never attempt to pour the water into the acid, but always add the acid, a little at a time, to the water. The addition of the acid to the water does not make simply a mechanical mixture of the two but creates a solution in the formation of which a considerable amount of heat is liberated. Consequently, if the acid be poured into the water too fast, the containing vessel may be broken by the heat. For the same reason, if the water be poured into the acid, the chemical reaction will be very violent, and the acid itself will be spattered about. Sulphuric acid is highly corrosive; it will cause painful burns whenever it comes in contact (even in dilute solution) with the skin and will quickly destroy any fabric or metal on which it falls. It will also attack wood, for which reason nothing but glass, earthenware, or hard rubber containers should be employed.

Specific Gravity. The weight of a liquid as compared with distilled water is known as its specific gravity. Distilled water at 60° F. is 1, or unity. Liquids heavier than distilled water have a specific gravity greater than unity; lighter liquids, such as gasoline, have a specific gravity less than that of distilled water. Concentrated sulphuric acid (battery acid, as received from the manufacturer) is a heavy oily liquid having a specific gravity of about 1.835. A battery will not operate properly on acid of full strength, and it is therefore diluted with sufficient water to bring it down to 1.275. This, however, is the specific gravity of the electrolyte only when the battery is fully charged. The specific gravity of the electrolyte affords the most certain indication of the condition of the battery at any time, and its importance in this connection is outlined at considerable length under the head of Hydrometer Tests. The desired specific gravity can be easily secured by adding concentrated sulphuric acid to the water. Never add the water to the acid as it will cause undue heat.

Action of Cell on Charge. When the elements described are immersed in a jar of electrolyte of the proper specific gravity, and terminals are provided for connecting to the outside circuit, the cell is complete. As the lead-plate storage battery produces current at a potential of but two volts per cell, however, a single cell is rarely used. The lowest number of cells in practical use is the three-cell unit of the 6-volt battery used for starting and lighting on the automobile. The different cells of the battery are usually permanently connected together by heavy lead straps, while detachable terminals are provided for connecting the battery to an outside circuit. When the charging current is sent through the cell, the action is as follows: The original storage-battery cell of Planté consisted simply of two plates of lead; when the current was sent through such a cell on charge, peroxide of lead was deposited on the positive plate and spongy metallic lead on the negative. This was termed "forming" the plate. By modern methods of manufacture, this active material is formed into a paste with dilute sulphuric acid, and is pressed into the grids. On being charged, this acid is forced out of the plates into the electrolyte, thus raising the specific gravity of the electrolyte. When practically all of this acid has been transferred from the active material of the plates to the solution, or electrolyte, the cell is said to be fully charged and should then show a specific gravity reading of 1.275 to 1.300. The foregoing refers of course to the initial charge. After the cell has once been discharged, the active material of both groups of plates has been converted into lead sulphate. The action on charge then consists of driving the acid out of the plates and at the same time reconverting the lead sulphate into peroxide of lead in the positive plates and into spongy metallic lead in the negative plates.

Action of Cell on Discharge. The action of the cell on discharge consists of a reversal of the process just described. The acid which has been forced out of the plates into the electrolyte by the charging current again combines with the active material of the plates, when the cell is connected for discharge to produce a current. When the sulphuric acid in the electrolyte combines with the lead of the active material, a new compound, lead sulphate, is formed at both plates. This lead sulphate is formed in the same way that sulphuric acid, dropped on the copper-wire terminals, forms copper sulphate, or dropped on the iron work of the car, forms iron sulphate. In cases of this kind, it will always be noted that the amount of sulphate formed is all out of proportion to the quantity of metal eaten away. In the same manner, when the sulphuric acid of the electrolyte combines with the lead in the plates to form lead sulphate, the volume is such as to completely fill the pores of the active material when the cell is entirely discharged. This makes it difficult for the charging current to reach all parts of the active material and accounts for the manufacturers' instructions, never to discharge the battery below a certain point.

As the discharge progresses, the electrolyte becomes weaker by the amount of acid that is absorbed by the active material of the plates in the formation of lead sulphate, which is a compound of acid and lead. This lead sulphate continues to increase in bulk, filling the pores of the plates, and as these pores are stopped up by the sulphate, the free circulation of the acid is retarded. Since the acid cannot reach the active material of the plates fast enough to maintain the normal action, the battery becomes less active.

which is indicated by a rapid falling off in the voltage. Starting at slightly over 2 volts per cell when fully charged, this voltage will be maintained at normal discharge rates with but a slight drop, until the lead sulphate begins to fill the plates. As this occurs, the voltage gradually drops to 1.8 volts per cell and from that point on will drop very rapidly. A voltage of 1.7 volts per cell indicates practically complete discharge, or that the plates of the cell are filled with lead sulphate and that the battery should be placed on charge immediately.

During the normal discharge, the amount of acid used from the electrolyte will cause the specific gravity of the solution to drop 100 to 150 points, so that if the hydrometer showed a reading of 1.280 when the cell was fully charged, it will indicate but 1.130 to 1.180 when it is exhausted, or completely discharged. The electrolyte is then very weak; in fact, it is little more than pure water. Practically all of the available acid has been combined with the active material of the plates. While the acid and the lead combine with each other in definite proportions in producing the current on discharge, it is naturally not possible to provide them in such quantities that both are wholly exhausted when the cell is fully discharged. Toward the end of the discharge, the electrolyte becomes so weak that it is no longer capable of producing current at a rate sufficient for any practical purpose. For this reason, an amount of acid in excess of that actually used in the plates during discharge is provided. This is likewise true of the active material.

Capacity of a Battery. The amount of current that a cell will produce on discharge is known as its capacity and is measured in ampere hours. It is impossible to discharge from the cell as much current as was needed to charge it, the efficiency of the average cell of modern type when in good condition being 80 to 85 per cent, or possibly a little higher when at its best, i.e., after five or six discharges. In other words, if 100 ampere hours are required to charge a battery, only 80 to 85 ampere hours can be discharged from it. This ampere-hour capacity of the cell depends upon the type of plate used, the area of the plate, and the number of plates in the cell, i.e., total positive-plate area opposed to total negative-plate area. To accomplish this, both outside plates in a cell are made negative. The ampere-hour capacity of a battery, all the cells of which are connected up as a single series, is the same as that of any single cell in the series; as in connecting up dry cells in series, the current output is always that of a single cell, while the voltage of the current increases 1½ volts for each cell added to the series. In the case of the storage battery, it increases two volts for each cell.

The capacity of the cell as thus expressed in ampere hours is based on its normal discharge rate or on a lower rate. For example, take a 100-ampere-hour battery. Such a battery will produce current at the rate of 1 ampere for practically 100 hours, 2 amperes for 50 hours, or 5 amperes for 20 hours; but as the discharge rate is increased beyond a certain point, the capacity of the battery falls off. The battery in question would not produce 50 amperes of current for 2 hours. This is because of the fact that the heavy discharge produces lead sulphate so rapidly and in such large quantities that it quickly fills the pores of the active material and prevents further access of the acid to it. Thus, while it will not produce 50 amperes of current for 2 hours on continuous discharge, it will be capable of a discharge as great or greater than this by considerable, if allowed periods of rest between. When on open circuit, the storage battery recuperates very rapidly. It is for this reason that when trying to start the switch should never be kept closed for more than a few seconds at a time. Ten trials of 10 seconds each with a half-minute interval between them will exhaust the battery less than will spinning the motor steadily for a minute and forty seconds.

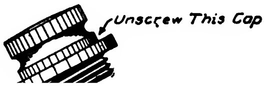


Fig. 383. Section of Willard Starting Battery, Showing Mud Space

Construction Details. For automobile starting and lighting service, the elements of the cells are placed in insulating supports in the bottom of the hard rubber jars and sealed in place. These supports hold the plates off the bottom of the jar several inches in the later types of starting batteries. Figs. 383 and 384 show sections of the Willard starter battery and another standard type This is known as the mud space and is designed to receive the accumulation of sediment consisting of the active material which is shaken off the plates in service. This active material is naturally a good electrical conductor, and if it were allowed to come in contact with the bottoms of the groups of plates, it would short-circuit the cell. Sufficient space is usually allowed under the plates to accommodate practically all of the active material that can be shed by the plates during the active life of the cell. In a battery having cells of this type, it is never necessary to wash the cells, as the elements themselves would require renewal before the sediment could reach the bottom of the plates.

Fig. 384. Typical Starting Battery with Plates Cut Down, Showing Assembly

In sealing the elements into the jar, a small opening is left for the purpose of adding distilled water as well as to permit the escape of the gas when the battery is charging. Except when being used for refilling the jars, this opening is closed by a soft rubber stopper which has a small perforation through which the hydrogen passes out of the cell when the latter is gassing, as explained later. The different cells of a battery are electrically connected by heavy lead straps, these strips being usually burned onto the plates by the lead-burning process.

Edison Cell Not Available. It will be noted that the foregoing description has been confined entirely to the lead-plate type of storage battery and that no mention has been made of the Edison cell. The latter is not available for starting service on the automobile, because its internal resistance is too high to permit the extremely heavy discharge rate that is necessary. In extremely cold weather or where the engine is unusually stiff for other reasons, this may be as high as 300 amperes momentarily, while, under ordinary conditions, it will reach 150 to 200 amperes at the moment of closing the switch. The efficiency of the Edison cell also drops off very markedly in cold weather, though this is also true to a lesser extent of the lead-plate type.

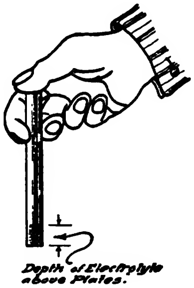


Fig. 385. Diagram Showing Method of Measuring Height of Electrolyte over Plates
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

CARE OF THE BATTERY

The following instructions are given about in the order in which it is necessary to apply them in the care of a storage battery.

Adding Distilled Water. In order to function properly, the plates in the cells must be covered by the electrolyte at all times to a depth of half an inch. Fig. 385 shows a handy method of determining this definitely. A small piece of glass tube, open at both ends, is inserted in the vent hole of the battery until it rests on the tops of the plates. A finger is then pressed tightly on top of the upper end of the tube, and the tube is withdrawn. It will bring with it at its lower end an amount of acid equivalent to the depth over the plates. This should always be returned to the same cell from which it was taken. The electrolyte consists of sulphuric acid and water. The acid does not evaporate, but the water does. The rapidity with which the water evaporates will depend upon the conditions of charging. For example, if a car is constantly driven on long day runs and gets very little night use, the storage battery is likely to be continually overcharged and may need the addition of water to the electrolyte as often as every three days, whereas, in ordinary service, once a week would be sufficient. Even with intermittent use, the battery should not be allowed to run more than two weeks without an inspection of the level of the electrolyte and the addition of distilled water, if necessary. Distilled water is always specified, since the presence of impurities in the water would be harmful to the battery, this being particularly the case where they take the form of iron salts. Where it is not convenient to procure distilled or rain water in sufficient quantities, samples of the local water supply may be submitted to any battery manufacturer for analysis.

While it is necessary to maintain the electrolyte one-half inch over the plates, care must be taken not to exceed this, for, if filled above this level, the battery will flood when charged, owing to the expansion with the increasing temperature. The best time for adding water is just before the car is to be taken out for several hours of use. It may be done most conveniently with a glass and rubber syringe of the type used with the hydrometer. Care should be taken when washing the car to see that no water is allowed to enter the battery box, as it is likely to short-circuit the cells across their lead connectors and to carry impurities into the cells themselves.

Adding Acid. When the level of the electrolyte in the cell becomes low, it is, under normal conditions, caused by the evaporation of the water, and this loss should be replaced with water only. *There being no loss of acid, it should never be necessary to add acid to the electrolyte during the entire life of the battery.* When a jar leaks or is accidentally upset, and some of the solution lost, the loss should be replaced with electrolyte of the same specific gravity as that remaining in the cell, and not with full strength acid nor with water alone. The former would make the solution too heavy, while the latter would make it too weak. Consequently, unless acid is actually known to have escaped from the cell, none should ever be added to it. Under the sections on the Hydrometer and Specific Gravity, further reasons are given why no acid or electrolyte should be added to the cell under normal conditions, and the causes which would seem to make the addition of acid necessary are explained.

Hydrometer. Next to the regular addition of distilled water to the cells, the garage man will be called upon most frequently to test the condition of the cells with the hydrometer. This is termed taking the specific gravity and is one of the most important tests in connection with the care of the battery. The specific gravity of a liquid is determined by means of an instrument consisting of a weighted glass tube having a scale marked on it. This instrument is the hydrometer, and in distilled water at 60 degrees it should sink until the scale comes to rest at the surface of the liquid at the division 1.000. The lighter the liquid, the further the instrument will sink in it; the heavier the liquid, the higher the instrument will float. For constant use in connection with the care of lighting and starting batteries, the hydrometer shown in Fig. 386 will be found the most convenient. Where the battery is located on the running board of the car, the test may be made without removing the syringe from the cell, but care must be taken to hold it vertical to prevent the hydrometer from sticking to the sides of the glass barrel. Wherever possible, the reading should be made without removing the syringe from the vent hole of the cell, so that the electrolyte thus withdrawn may always be *returned to the same cell.* Where the battery is located in a position difficult of access, as under the floor boards, the syringe may be drawn full of electrolyte and then lifted out; as the soft rubber plug in the bottom of the glass barrel is in the form of a trap, when the instrument is held vertical, the solution will not run out while the reading is being taken.

Fig. 386. Syringe Hydrometer Set

Failure to replace the electrolyte in the same cell from which it was taken will result in destroying the uniformity of the cells. For example, if electrolyte has been withdrawn from cell No. 1 of the battery and, after taking the reading, it is put into cell No. 2, the amount taken from No. 1 must later be made up by adding water, and the solution will be that much weaker, while the electrolyte of No. 2 will be correspondingly stronger.

Hydrometer Tests. In taking a hydrometer reading, first see that the instrument is not held by the sides of the glass syringe barrel; then note the level of the instrument in the liquid by looking at it from below, i.e., hold it up above the level of the eye. Reading the hydrometer in this way is found to give more accurate results than looking down upon it. While the hydrometer affords the best single indication of the condition of the battery—the cells should test 1.250 to 1.300 when fully charged and 1.150 when fully discharged, below which point they should never be allowed to go—there are conditions under which the instrument may be entirely misleading. For example, when fresh distilled water is added to a cell to bring the solution up to the proper level, the additional water does not actually combine with the electrolyte until the cell has been on charge for some time. Consequently, if a hydrometer reading were taken of that particular cell just after the water had been added, the test would be misleading, as it would apparently show the cell to be nearer the fully discharged state than it actually was, owing to the low specific gravity of the electrolyte. If, on the other hand, fresh electrolyte or pure acid has been added to a cell just prior to taking readings, and without the knowledge, of the tester the reading would apparently show the battery to be fully charged, whereas the reverse might be the case. In this instance, the specific gravity would be higher than it should be. To determine accurately the condition of the cells in such circumstances, the hydrometer readings would have to be checked by making tests with the voltmeter, as described later.

Under average conditions, however, the hydrometer alone will closely indicate the state of charge, and its use should always be resorted to whenever there is any question as to the condition of a battery. For instance, an irate owner will sometimes condemn the battery for failure of the starting motor to operate and will be absolutely positive that the battery has been fully charged, since he has been driving in daylight for hours. The hydrometer reading will show at once whether the battery is charged or not. If it is not, it will indicate either that the generator, its regulator, or the battery cut-out are not working properly, or that there is a short-circuit or a ground somewhere in the lighting or ignition circuits which permits the battery to discharge itself. Another more or less common complaint, the cause of which may be definitely assigned one way or the other by the aid of the hydrometer is that "the battery is not holding its charge". Except where it is allowed to stand for long periods without use, as where a car is laid up for a month or more, there is no substantial decrease in the capacity simply through standing, unless the battery is allowed to stand in a discharged condition.

Consequently, the owner's impression that the charge of the battery is mysteriously leaking away overnight through some shortcoming of the cells themselves is not correct. If there is a fault, it is probably in the wiring; or a switch may have been left on inadvertently; or, as is very often the case, the car is not driven long enough in daylight to permit the generator to charge the battery sufficiently. When driving at night with all lights on, as is commonly the custom, the generator supplies very little current in excess of that required by the lamps. As a result, the battery receives but a fraction of its normal charge, so that one or two attempts to use the starting motor exhaust it. A hydrometer test made just before using the starting motor will show that there is only a small fraction of a charge in the cells, so that they are not capable of supplying sufficient current to turn the engine over longer than a few seconds. The hydrometer is equally valuable in indicating when a battery is being overcharged, though this is a condition which carries its own indication, known as gassing, which is described in detail under that head.

Variations in Readings. Specific-gravity readings between 1.275 and 1.300 indicate that the battery is fully charged; between 1.200 and 1.225, that the battery is more than half discharged; between 1.150 and 1.200, that the battery is quickly nearing a fully discharged condition and must be recharged very shortly, otherwise injury will result. Below 1.150 the battery is entirely exhausted and must be recharged immediately to prevent the plates from becoming sulphated, as explained in the section covering that condition.

Where the specific gravity in any cell tests more than 25 points lower than the average of the other cells in the battery, it is an indication that this cell is out of order. Dependence should not be placed, however, on a single reading where there is any question as to the specific gravity. Take several readings and average them. Variations in cell readings may be caused by internal short-circuits in the cell; by putting too much water in the cell and causing a loss

PLATE 97—LOCOMOBILE WIRING DIAGRAM FOR

PLATE 98—LOCOMOBILE WIRING DIAGRAM FOR 1913 MODELS 38, 48, BOSCH DUAL IGNITION SYSTEM

PLATE 99—LOCOMOBILE WIRING DIAGRAM FOR 1915 CLOSED CARS, WESTINGHOUSE SYSTEM

PLATE 100—LOCOMOBILE WIRING DIAGRAM OF 1919-20 MODEL 48, WESTINGHOUSE STARTING AND LIGHTING, BERLING MAGNETO IGNITION SYSTEMS

PLATE 101—MADISON WIRING DIAGRAM FOR 1916-17-18 MODELS, 6- 8-CYLINDER, REMY SYSTEM

PLATE 102—MARMON WIRING DIAGRAM FOR 1920 MODEL 34-B, DELCO SYSTEM

PLATE 103—MAXWELL WIRING DIAGRAM FOR 1917 TRUCK MODEL, AUTO-LITE SYSTEM

PLATE 104—MAXWELL WIRING DIAGRAM OF 1920 TWO-UNIT INSTALLATION, SIMMS-HUFF STARTING AND LIGHTING, ATWATER-KENT IGNITION SYSTEMS

PLATE 105—MAXWELL WIRING DIAGRAM OF 1920 SINGLE-UNIT THIRD-BRUSH, SIMMS-HUFF STARTING AND LIGHTING, ATWATER-KENT IGNITION SYSTEMS

DAVIS SYSTEM

PLATE 108—METZ WIRING DIAGRAM OF 1920 MASTER 6 MODEL, WESTINGHOUSE STARTING AND LIGHTING, CONNECTICUT IGNITION SYSTEMS

PLATE 110—MOLINE TRACTOR WIRING DIAGRAM OF MODEL D, REMY SYSTEM

PLATE 111—MITCHELL WIRING DIAGRAM OF 1916-17 MODEL C-42, REMY SYSTEM

PLATE 112—MITCHELL WIRING DIAGRAM OF 1920 MODEL F-40, REMY SYSTEM

of electrolyte through flooding or overflowing; or by loss of electrolyte from a cracked or leaky jar. Internal short-circuits may result from a broken separator or from an accumulation of sediment in the mud space of the jars reaching the bottom of the plates.

Quite a substantial percentage of all the troubles experienced with starting batteries, which are only too often neglected until they give out, is caused by letting the electrolyte get too low in the jars. The effect of this is to weaken the battery, causing it to discharge more readily, and frequently resulting in harmful sulphating of the plates and injury to the separators. When such sulphating occurs, it permits the plates to come into contact with each other, and an internal short-circuit results. The importance of always maintaining the electrolyte one-half inch above the tops of the plates will be apparent from this.

One of the most frequent causes of low electrolyte in a single cell is the presence of a cracked or leaky jar. If one of the cells requires more frequent addition of water than the others to maintain the level of its electrolyte, it is an indication that it is leaking. Where all the cells of a battery require the addition of water at unusually short intervals, it is an indication that the battery is being constantly overcharged. (See Gassing.) Unless a leaky jar is replaced immediately, the cell itself will be ruined, and it may cause serious damage to the remainder of the battery. Jars are often broken owing to the hold-down bolts or straps becoming loose, thus allowing the battery to jolt around on the running board, or they may be broken by freezing. The presence of a frozen cell in a battery shows that it has been allowed to stand in an undercharged condition in cold weather, as a fully charged cell will not freeze except at unusually low temperatures.

Frozen Cells. In some cases, the cells may freeze without cracking the jars. This will be indicated by a great falling off in the efficiency of the cells that have suffered this injury, or in a totally discharged condition which cannot be remedied by continuous charging. In other words, the battery is dead and the plates are worthless except as scrap lead. In all cases where cells have been frozen, whether the jar has cracked or not, the plates must be replaced at once. It must always be borne in mind that low temperatures seriously affect the efficiency of the storage battery and that care should be taken to keep it constantly in a charged condition. A variation in the temperature also affects the hydrometer readings themselves. The effect of the temperature on the hydrometer tests is explained under Adjusting the Specific Gravity.

Low Cells. When one cell of the battery tests more than 25 points below the specific gravity of the others, as shown by the average of several readings taken of each, it should be placed on charge separately from an outside source of current. This may be done without removing it from the car or disconnecting it from the other cells, since the charging leads may be clipped to its terminal posts. If no other facilities are available and direct-current service is at hand, use carbon lamps as a resistance in the manner illustrated on another page. As the normal charging rate of the average starting battery is 10 to 15 amperes or more, that many 32-c.p. carbon filament lamps may be used in the circuit. Where only alternating current is available, a small rectifier, as described under Charging from Outside Sources, will be found most convenient in garages not having enough of this work to warrant the installation of a motor-generator. After the low cell has been on charge for an hour or two, note whether or not its specific gravity is rising, by taking a hydrometer reading. If, after several hours of charging, its specific gravity has not risen to that of the other cells, it is an indication that there is something wrong with the cell, and it should be cut out. (See Replacing a Jar and Overhauling the Battery.)

Adjusting the Specific Gravity. Except in such cases as those mentioned under Hydrometer, where water has been added to the electrolyte just before testing, or electrolyte has been added without the knowledge of the tester, specific gravity of the electrolyte is the best indication of the condition of the cell, and the treatment to be given should always be governed by it. As explained in the section on Action on Charge and Discharge, the acid of the electrolyte combines with the active material of the plates to produce the current on discharge. The further the cell is discharged the more acid there will be in the plates, and the less in the solution. Consequently, low-gravity readings practically always mean lack of acid in the solution, and that implies lack of charge. Unless there is something wrong with the cell, charging will restore the acid to the electrolyte and bring the specific-gravity readings up to normal. In case a jar is leaking or has been overturned and lost some of its electrolyte, no amount of charging will bring its specific gravity up to the proper point.

The gravity readings of the cells vary somewhat in summer and winter, and they also decrease with the age of the plates, but the battery will continue to give good service as long as its specific gravity rises to between 1.250 and 1.300 when fully charged. In case it rises above 1.300, there is an indication that excess acid has been added to the electrolyte, and this must be corrected by drawing off some of the electrolyte with the syringe and replacing it with distilled water. A gradually decreasing specific gravity in all the cells of a battery is an indication that sediment is accumulating in the bottom of the jars and that the battery, if of the old type with low mud space, requires washing; if of the later type with high mud space, that its elements require renewal. Before accepting this conclusion, however, make certain that the low reading is not due to insufficient charging. In actual practice, starter batteries seldom remain long enough in service without overhauling ever to need washing.

Many starter batteries are kept in an undercharged condition so constantly, owing to frequent use of the starting motor with but short periods of driving in between, that they should be put on charge from an outside source at regular intervals. In fact, this is the only method of determining definitely whether the battery itself is really at fault or whether it is the unfavorable conditions under which it is operating. Where the cells give a low reading, no attempt should ever be made to raise the specific gravity of the electrolyte by adding acid, until the battery has been subjected to a long slow charge. The maximum specific gravity of the electrolyte is reached when all the acid combined in the active material of the plates has been driven out by the charging current. Adding acid will increase the specific gravity, but it will not increase the condition of charge; it will simply give a false indication of a charged condition. For example, if the electrolyte of a cell tested 1.225, and, without giving it a long charge, acid were added to bring the specific gravity up to 1.275, it would then rise to 1.325 if put on charge, showing that 50 points of acid had remained combined in the plates when the low readings were taken.

The necessity for adjusting the specific gravity of the electrolyte in a cell can only be determined by first bringing it to its true maximum. To do this with a starter battery, it must be put on charge from an outside source at a low rate, say 5 amperes, and kept on charge continuously until tests show that the specific gravity of the electrolyte has ceased to rise. This may take more than twenty-four hours, and readings should be taken every hour or so, toward the end of the charge. Should the battery begin to gas violently while tests show that the specific gravity is still rising, the charging current should be reduced to stop the gassing, or, if necessary, stopped altogether for a short time and then renewed.

If after this prolonged charge, the specific gravity is not more than 25 points below normal, some of the solution may be drawn off with the syringe and replaced with small quantities of 1.300 electrolyte, which should be added very gradually to prevent bringing about an excess. Should the specific gravity be too high at the end of the charge, draw off some of the electrolyte and replace it with distilled water to the usual level of one-half inch over the plates. A charge of this kind is usually referred to as a conditioning charge and, given once a month, will be found very greatly to improve starter batteries that are constantly undercharged in service.

Temperature Corrections. All specific-gravity readings mentioned are based upon a temperature of 70° F. of the electrolyte, and as the electrolyte, like most other substances, expands with the heat and contracts with the cold, its specific gravity is affected by variations of temperature. This, of course, does not affect its strength, but as its strength is judged by its specific gravity, the effect of the temperature must be taken into consideration when making the tests. The temperature in this connection is not that of the surrounding air but that of the electrolyte itself, and as the plates and solution of a battery increase in temperature under charge, the electrolyte may be 70° F. or higher, even though the outside air is close to zero. Consequently, the only method of checking this factor accurately is to insert a battery thermometer in the vent hole of the cell. If, on the other hand, the battery has been standing idle for some time in a cold place, the electrolyte has the same temperature as the surrounding air, and a hydrometer reading taken without a temperature correction would be very misleading.

For example, assume that the car is standing in a barn in which the temperature is 20° F. and that it has not been running for some time so that the electrolyte is as cold as the surrounding air. A hydrometer reading shows the specific gravity of the electrolyte to be 1.265, which would indicate that the battery was approximately fully charged. But the correction for temperature amounts to one point (.001) for each three degrees above or below 70° F., and in this case a difference of 50 degrees would have to be allowed for. This amounts to practically 18 points, and the specific gravity of the cells is 1.265 minus 18, or 1.247. The battery is accordingly three-quarters charged, instead of fully charged as the uncorrected reading would appear to indicate. The electrolyte contracts with the drop in temperature, and its specific gravity becomes correspondingly higher without any actual increase in its strength. The opposite condition will be found when the battery has commenced to gas so violently that the temperature of the electrolyte is raised to 100° to 105° F. At the former figure there would be a difference of 30 degrees, or 10 points, to allow for, in which case a specific gravity reading of 1.265 would actually be 1.275. Hydrometer scales, with a a temperature scale showing at a glance the corresponding correction necessary, simplify the task of correcting the readings; but to do this properly a battery thermometer must be employed, as the temperature of the electrolyte itself is the only factor to be considered.

Gassing. When an electric current is sent through a storage-battery cell, it immediately attacks the lead sulphate into which the active material of both the positive and the negative plates has been converted during the discharge and begins to reconvert it into peroxide of lead at the positive plate and into spongy metallic lead at the negative. As long as there is an ample supply of this lead sulphate on which the current may work, as in a fully discharged battery, the entire amperage being sent through the battery is restricted to carrying on this process. In other words, the current will always do the easiest thing first by following the path of least resistance. When the cell is in a discharged state, the easiest thing to do is to decompose the lead sulphate. As there is a comparatively large amount of this lead sulphate in a fully discharged battery, a correspondingly large amount of current can be used in charging at the start. But as the amount of sulphate progressively decreases with the charge, a point is reached at which there is no longer sufficient sulphate remaining to utilize all the current that is passing through the cell.

The excess current will then begin to do the next easiest thing, which is to decompose the water of the electrolyte and liberate hydrogen gas. This gassing is not owing to any defect in the battery, as some owners seem to think, but is simply the result of overcharging it. In one instance, a car owner condemned the starting battery with which his machine was equipped, for the reason that it was "always boiling". In fact, it "boiled" itself to pieces and had to be replaced by the manufacturer of the car after only a few months of service; while, as a matter of fact, the conditions under which the car was driven were wholly responsible. It was used for long runs in the day time with infrequent stops, and was rarely run at night; therefore, the battery was continually charging but seldom had an opportunity to discharge.

This erroneous impression is also closely interlinked with another that is equally common and equally harmful. This is that one of the functions of the battery cut-out is to break the circuit and prevent the battery from becoming overcharged. It is hardly necessary to add that this is not one of its functions, but that as long as the generator is being driven above a certain speed, the cut-out will keep the battery in circuit, and the generator will continue to charge it. Its only purpose is to prevent the battery from discharging itself through the generator when the speed of the generator falls to a point where its voltage would be overcome by that of the battery unless the battery were automatically disconnected. The cut-out does not protect the battery from being overcharged; only the driver or the garage man can do that by noting the conditions under which the car is operated and taking precautions to prevent the battery from overcharging.

Gassing is simply an indication that too much current is being sent into the battery. Another indication of the same condition is the necessity for refilling the cells with distilled water at very short intervals, as an excess charge raises the temperature of the electrolyte and causes rapid losses by evaporation. That is the reason why it is likely to be so harmful to the battery unless remedied, as if allowed to exceed 110° F., the active material is likely to be forced out of the grids, and the cells to be ruined. While it is essential that the battery be fully charged at intervals and that it be always kept well charged, continuously overcharging it is likely to be as harmful as allowing it to stand undercharged. Where the conditions of service cannot be altered to remedy the trouble, the regulator of the generator should be adjusted to lower the charging rate, or, if nothing else will suffice, additional resistance, controlled by an independent switch, may be inserted in the charging circuit. (The U.S.L. system has a provision to safeguard the battery against overcharge, termed the touring switch.)

Higher Charge Needed in Cold Weather. While the regulator of the generator is set by the manufacturer to give the best average results, and some makers warn the user against altering its adjustment, experience has demonstrated that a fixed adjustment of the regulation will not suffice for cars driven under all sorts of service conditions, nor for the same car as used at different seasons of the year. The efficiency of the storage battery is at its lowest in cold weather, which is the time when the demand upon it is greatest. A battery that would be constantly overcharged during the summer may not get more than sufficient current to keep it properly charged in winter, though driven under similar conditions in both seasons. On the other hand, a battery that is generally undercharged under summer conditions of driving will be practically useless in winter, as it will not have sufficient current to meet the demands upon it.

It may be put down as a simple and definite rule that if the battery of a starting system never reaches the gassing stage, it is constantly undercharged and is rapidly losing its efficiency, as the sulphate remaining on the plates becomes harder with age and prevents the circulation of the electrolyte. Even when in the best condition, the electrolyte cannot reach all of the active material in the plates, so that any reduction means a serious falling off. Likewise, when a battery is constantly gassing, it is in a continuous state of overcharge and is apt to be entirely ruined in a comparatively short time. The danger from undercharging is known as sulphating—the plates become covered with a hard coating of lead sulphate that the electrolyte cannot penetrate—while that from overcharging is due to the electrolyte and the plates reaching a dangerous temperature (105° F. or over) at which the active material is apt to be stripped from the grids. The conditions of service, on the average, are such that a battery can seldom be kept in good condition for any length of time on the charging current from the generator alone.

The hydrometer should be used frequently to keep track of its condition and, at least once a month, it should be given a long conditioning, or equalizing, charge, as it is variously termed. This charge is required because of the fact that, under ordinary conditions, a battery seldom receives a complete charge and that every time it is discharged without this being followed by a charge which is prolonged until the electrolyte has reached its maximum specific gravity, more lead sulphate accumulates in the plates. The object of the long charge is to convert this lead sulphate into peroxide of lead at the positive plate and into spongy metallic lead at the negative plate, as explained further under the head of Sulphating.

Sulphating. At the end of a discharge, both sets of plates are covered with lead sulphate. This conversion of the active material of the plates into lead sulphate, which takes place during the discharge, is a normal reaction and, as such, occasions no damage. But if the cells are allowed to stand for any length of time in a discharged condition, the sulphate not only continues to increase in bulk, but becomes hard. It is also likely to turn white, so that white spots on the plates of a battery when it is dismantled are an indication that the cells have been neglected. In this condition, the plates have lost their porosity to a certain extent and it is correspondingly more difficult for the charging current to penetrate the active material. When a battery has stood in a discharged condition for any length of time, it becomes sulphated. The less current it has in it at the time and the longer it stands, the more likely it is to be seriously damaged.

Where a car is used but little in the daytime, and then only for short runs with more or less frequent stops, the battery never has an opportunity to become fully charged. The demands of the starting motor and the lights are such that the battery is never more than half charged at any time. Consequently, there is always a certain proportion of the lead sulphate that is not reconverted, but which remains constantly in the plates. As already mentioned, this condition does not remain stationary; the sulphate increases in amount and the older portions of it harden. This represents a loss of capacity which finally reaches a point where the cells are no longer capable of supplying sufficient current (holding enough of the charge, as the owner usually puts it) to operate the starting motor. A battery that has been operating under conditions of this kind is not prepared for the winter's service, which accounts for the great number of complaints about the poor service rendered by starting systems in the early part of every winter. As long as the weather is warm, the battery continues to supply sufficient current in spite of the abuse to which it is subjected, but when cold weather further reduces its efficiency, it is no longer able to meet the demand.

The only method of preventing this and of remedying it after it has occurred is the equalizing charge mentioned in the previous section. Long continued and persistent charging at a low rate will cure practically any condition of sulphate, the time necessary being proportionate to the degree to which it has been allowed to extend. It is entirely a question of time, and, as a high rate would only produce gassing, which would be a disadvantage, the rate of charge must be low. In case the cells show any signs of gassing, the charge must be further reduced.

Extra Time Necessary for Charging. The additional length of time necessary for charging a battery that has been constantly kept in an undercharged condition is strikingly illustrated by the following test made with an electric vehicle battery: The cells were charged to the maximum, and the specific gravity regulated to exactly 1.275 with the electrolyte just ½ inch above the tops of the plates, this height being carefully marked. The battery was then discharged and recharged to 1.265 at the normal rate in each case. The specific gravity rose from 1.265 to 1.275 during the last hour and a half of the charge. During the following twelve weeks, the battery was charged and discharged daily, each charge being only to 1.265, thus leaving 10 points of acid still in the plates. At the end of the twelve weeks, the charge was continued to determine the time required to regain the 10 points and thus restore the specific gravity to the original 1.275. Eleven hours were needed, as compared with the hour and half needed at first. This test further illustrates why it is necessary to give a battery an occasional overcharge or equalizing charge to prevent it becoming sulphated. Had the battery in question been charged daily to its maximum of 1.275 and discharged to the same extent during the twelve weeks, 9½ hours of the last charge would have been saved. These periods of time, of course, refer to the charging of the electric-vehicle battery, but they indicate in a corresponding manner the loss of efficiency suffered by the starting battery owing to its being continually kept in an undercharged condition.

Restoring Sulphated Battery. There are only three ways in which a battery may become sulphated: The first and most common of these is that it has not been properly charged; second, excess acid has been added to the electrolyte; third, an individual cell may become sulphated through an internal short-circuit or by drying out, as might be caused by failure to replace evaporation with water, or failure to replace promptly a cracked jar. The foregoing only holds good, however, where the sediment has not been allowed to reach the bottom of the plates, and where the level of the electrolyte has been properly maintained by replacing evaporation with distilled water.

To determine whether a battery is sulphated or not—it having been previously ascertained that it does not need cleaning (washing)—it should be removed from the car (the generator should not be run with the battery off the car without complying with the manufacturer's instructions in each case, usually to short-circuit or bridge certain terminals on the generator itself) and given an equalizing charge at its normal rate. The normal rate will usually be found on the name plate of the battery. If the battery begins to gas at this rate, the rate must be reduced to prevent gassing, and lowered further each time the cells gas. Frequent hydrometer readings should be taken, and the charge should be continued as long as the specific gravity continues to increase. A battery is sulphated only when there is acid retained in the plates. When the specific gravity reaches its maximum, it indicates that there is no more sulphate to be acted upon, since, during the charge, the electrolyte receives acid from no other source. With a badly sulphated battery, the charge should be continued until there has been no further rise in the specific gravity of any of the cells for a period of at least twelve hours. Maintain the level of the electrolyte at a constant height by adding pure water after each test with the hydrometer (if water were added just before taking readings, the water would rise to the top of the solution and the reading would be valueless). With a battery on a long charge, the battery thermometer should be used at intervals to check the temperature of the electrolyte, and the hydrometer readings should be corrected in accordance with the temperature.

Specific Gravity too High. Should the specific gravity of any of the cells rise above 1.300, draw off the electrolyte down to the top of the plates and put in as much distilled water as possible without flooding the cell. Continue the charge and, if the specific gravity again exceeds 1.300, this indicates that acid has been added during the previous operation of the battery. The electrolyte should then be emptied out and replaced with distilled water and the charge continued. The battery can only be considered as restored to efficient working condition when there has been no rise in the specific gravity of any of the cells during a period of at least twelve hours of continuous charging.

Upon completion of the treatment, the specific gravity of the electrolyte should be adjusted to its proper value of 1.280, using distilled water or 1.300 acid, as necessary. In cases where one cell has become sulphated while the balance of the battery is in good condition, it is usually an indication that there is a short-circuit or other internal trouble in the cell, though this does not necessarily follow. To determine whether or not it is necessary to dismantle the cell, it may first be subjected to a prolonged charge, as above described. If its specific gravity rises to the usual maximum, the condition may be considered as remedied without taking the cell apart. It is the negative plate which requires the prolonged charge necessary to restore a sulphated battery. When sulphated, the active material is generally of light color and either hard and dense or granular and gritty, being easily disintegrated. Unless actually buckled or stripped of considerable of their active material, the positive plates are unchanged in appearance and can be restored to operative condition, though their life will be shortened by this abuse. Sulphated plates of either type should be handled as little as possible. By keeping close check with the hydrometer on the condition of the starting battery and, where it is not being kept in an overcharged condition constantly, giving it an equalizing charge once a month, the charge being continued until the cells no longer increase in specific gravity after a period of several hours. and the reading of all the cells being within at least 25 points of each other, sulphating may be avoided entirely.

Internal Damage. This trouble is usually caused by a short-circuit, owing either to an accumulation of sediment reaching the plates or to the breaking of a separator, which may be caused by the active material being forced out of the grid, usually termed buckling, which is caused by overheating. It is important to be able to determine whether or not the low efficiency of a certain cell is caused by internal trouble without having to dismantle the cell. The repair man's most important aid for this class of work is the high-grade portable voltmeter mentioned in connection with other tests of the starting and lighting system.

Voltage Tests. Under some conditions, the voltmeter will also indicate whether the battery is practically discharged or not, but, like the hydrometer, it should not be relied upon alone. To insure accuracy, it must be used in conjunction with the hydrometer. Since a variation as low as .1 (one-tenth) volt makes considerable difference in what the reading indicates regarding the condition of the battery, it will be apparent that a cheap and inaccurate voltmeter would be a detriment rather than an aid. The instrument illustrated in connection with tests of other parts of starting and lighting systems (see Delco) is of the type required for this service. Complete instructions for its use will be received with the instrument, and these must be followed very carefully to avoid injuring it. For example, on the three-volt scale, but one cell should be tested; attempting to test the voltage of more than one cell on this scale is apt to burn out the three-volt coil in the meter. The total voltage of the number of cells to be tested must never exceed the reading of the particular scale being used at the time; otherwise, the coil of the scale in question will suffer, and the burning out of one coil will make it necessary to rebuild the entire instrument.

Clean Contacts Necessary. Where the voltage to be tested is so low, a very slight increase in the resistance will affect it considerably and thus destroy the accuracy of the reading. Make certain that the place on the connector selected for the contact point is clean and bright, and press the contact down on it firmly. To insure a clean bright contact point, use a fine file on the lead connector. The contact will be improved by filing the test points fairly sharp.

Even a thin film of dirt or a weak contact will increase the resistance to a point where the test is bound to be misleading. The positive terminal of the voltmeter must be brought into contact with the positive terminal of the battery, and the negative terminal of the voltmeter with the negative of the battery. If the markings of the cell terminals are indistinct, connect the voltmeter across any one cell. In case the pointer butts up against the stop at the left instead of giving a reading, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive of the battery. This test can be made with a voltmeter without any risk of short-circuiting the cell, as the voltmeter is wound to a high resistance and will pass very little current. Connecting an ammeter directly across a cell, however, would short-circuit it and instantly burn out the instrument.

How to Take Readings. It is one of the peculiarities of the storage cell that when on "open circuit", i.e., not connected in circuit with a load of any kind, it will always show approximately two volts, regardless of whether it is almost fully charged or almost the reverse. Consequently, voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are valueless, *except when a cell is out of order*. Therefore, a load should be put on the battery before making these tests. This can be done by switching on all the lamps. With the lights on, connect the voltmeter, as already directed, and test the individual cells. If the battery is in good condition, the voltage readings, after the load has been on for about ten minutes, will be but slightly lower than if the battery were on open circuit. This should amount to about .1 (one-tenth) volt. Should one or more of the cells be completely discharged, the voltage of these cells will drop rapidly when the lamps are first switched on and, when a cell is out of order, will sometimes show a reverse reading. Where the battery is nearly discharged, the voltage of each cell will be considerably lower than if the battery were on open circuit, after the load has been on for five minutes.

Detecting Deranged Cells. To distinguish the difference between cells that are merely discharged and those that are out of order, put the battery on charge, either from an outside source or by starting the engine, which should always be cranked by hand when any battery trouble is suspected. Then test again with the voltmeter. If the voltage of each cell does not rise to approximately two volts after the battery has been on charge for ten minutes or more, it is an indication of internal trouble which can be remedied only by dismantling the cell. (See instructions under that heading.)

Temperature Variations in Voltage Test. When making voltage tests, it must be borne in mind that the voltage of a cold battery rises slightly above normal on charge and falls below normal on discharge. The reverse is true of a warm battery in hot weather, i.e., the voltage will be slightly less than normal on charge and higher than normal on discharge. As explained in connection with hydrometer tests of the electrolyte, the normal temperature of the electrolyte may be regarded as 70° F., but this refers only to the temperature of the liquid itself as shown by the battery thermometer, and not to the temperature of the surrounding air. For the purpose of simple tests for condition, voltage readings on discharge are preferable, as variations in readings on charge mean little except to one experienced in the handling of storage batteries.

Joint Hydrometer and Voltmeter Tests. As already explained above, neither the hydrometer nor the voltmeter reading alone can always be taken as conclusive evidence of the condition of the battery. There are conditions under which one must be supplemented by the other to obtain an accurate indication of the state of the battery. In making any of the joint tests described below, it is important to take into consideration the four points following:

(1) The effect of temperature on both voltage and hydrometer readings.

(2) Voltage readings should be taken only with the battery discharging, as voltage readings on an idle battery in good condition indicate little or nothing.

(3) Never attempt to use the starting motor to supply a discharge load for the battery, because the discharge rate of the battery is so high while the starting motor is being used that even in a fully charged battery it will cause the voltage to drop rapidly.

(4) The voltage of the charging current will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, so that readings taken under such circumstances are not a good indication of the condition of the battery.

In any battery which is in good condition, the voltage of each cell at a normally low discharge rate, i.e., 5 to 10 amperes for a starter battery of the 6-volt type or slightly less for a higher voltage battery, will remain between 2.1 and 1.9 volts per cell until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or is in a bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on for a few minutes. The following joint hydrometer and voltmeter tests issued by the Prest-O-Lite Company of Indianapolis will be found to cover the majority of cases met with in actual practice.

(1) A voltage of 2 to 2.2 volts per cell with a hydrometer reading of 1.275 to 1.300 indicates that the battery is fully charged and in good condition.

(2) A voltage reading of less than 1.9 volts per cell, with a hydrometer reading of 1.200 or less indicates that the battery is almost completely discharged.

(3) A voltage reading of 1.9 volts or less per cell, with a hydrometer reading of 1.220 or more, indicates that excess acid has been added to the cell. Under these conditions, lights will burn dimly, although the hydrometer reading alone would appear to indicate that the battery was more than half charged.

(4) Regardless of voltage—high, low, or normal—any hydrometer reading of over 1.300 indicates that an excessive amount of acid has been added.

(5) Where a low voltage reading is found, as mentioned in cases 2 and 3, to determine whether the battery is in bad order or merely discharged, stop the discharge by switching off the load, and put the battery on charge, cranking the engine by hand, and note whether the voltage of each cell rises promptly to 2 volts or more. If not, the cell is probably short-circuited or otherwise in bad condition.

Cleaning a Battery. Electric vehicle batteries usually receive such careful and intelligent attention that the life of the battery is measured by the maximum number of charges and discharges of which the plates are capable under favorable conditions. To prevent any possibility of short-circuiting, a cell is cut out and opened after a certain number of discharges, and if the amount of sediment in the jar is approaching the danger point, the entire battery is opened and cleaned. With the old type starter cell, this would be necessary if the battery received the proper attention; with the modern or high mud-space type, cleaning is never necessary as the space is designed to accommodate all the active material that can fall from the plates without touching their under sides. As a matter of fact, the batteries of starting and lighting systems never last long enough to require cleaning out. They are either kept undercharged and thus become badly sulphated, or they are overcharged to a point where the temperature passes the danger mark frequently. When hot, the acid attacks and injures the wood separators so that the average life is about one year. Exceptions to this are found in those cases where the battery has been given proper attention, which results in unusually long life without the necessity of opening the cells for either cleaning or the insertion of new separators. These cases are so in the minority, however, that the battery manufacturers usually recommend that the car owner have his starting battery overhauled in the fall to put it in the best of condition for the winter as well as for the following year. Even where a battery has been given conscientious attention, the conditions of charging on the automobile are likely to vary so radically that it will be found almost impossible to keep the cells in a good state. Consequently, it is considered the best practice to give all starter batteries an overhauling once a year. The method of doing this is described in succeeding sections.

Fig. 387. Drilling Off Connectors
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

Replacing a Jar. When a cell requires the addition of distilled water more often than the other cells of the battery, or does not test to the same specific gravity as the others, it is usually an indication that there is a leak in the jar. Failure to give the same specific-gravity reading is not proof of this condition, as the cell may be low from other causes, but the loss of electrolyte is certain evidence of it. The only remedy is to replace the jar at fault.

After locating the cell in question, carefully mark the connectors so as to be sure to replace them the same way. Disconnect the cell from the others in the battery. This may be done either with the aid of brace and bit, which is used to drill down through the post of the connector, Fig. 387, or with a gasoline torch which should be applied carefully to the strap at the post. When the metal has become molten, pry the strap up on the post with a piece of wood. Do not use a screwdriver or other metal for this purpose as it is apt to short-circuit one or more of the cells. Care must also be taken not to apply so much heat that the post itself will be melted as this would make it difficult to reconnect the cell. For one not accustomed to handling the torch, it will be safer to drill out the post, as illustrated. Lift the complete cell out of the battery box and then use the torch to warm the jar around the top to soften the sealing compound that holds the cover, Fig. 388. Grip the jar between the feet, take hold of the two connectors and pull the element almost out of the jar, Fig. 389. Then grip the elements near the bottom to prevent the plates flaring out while transferring them to the new jar, taking care not to let the outside plates start down the outside of the jar, Fig. 390. After the element is in the new jar, reseal the cell by pressing the sealing compound into place with a hot putty knife. Fill the cell with 1.250 electrolyte to the proper point, the old electrolyte being discarded.

Fig. 388. Softening Sealing Compound on Cell

Before replacing the connectors, clean both the post and the inside of the eye of the connector by scraping them smooth with a knife. When the connector has been placed in position, tap it down firmly over the post to insure good contact. To complete the connection, melt the lead of the connector and the post at the top so that they will run together, and while the lead is still molten, melt in some more lead until the eye of the connector is filled level. This is termed lead burning and is described at greater length in a succeeding section. Where no facilities are at hand for carrying it out, it may be done with an ordinary soldering copper. The copper is brought to a red heat so that all the tinning is burned off, and no flux of any kind is used. The method of handling the soldering copper and the lead-burning strip to supply the extra metal required to fill the eye is shown in Fig. 391.

Fig. 389. Lifting Elements out of Jar by Hand

Fig. 390. Installing Elements in Jar

Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

Put the battery on charge from an outside source, and when the cells begin to gas freely, reduce the current to half the finishing rate given on the battery name plate and charge at this rate as long as there is any rise in the specific gravity of the electrolyte in this or any of the other cells. The maximum gravity has been reached when there has been no rise in the specific gravity for a period of three hours. If the gravity of the cell having the new jar is then over 1.280, draw off some of the electrolyte and replace it with distilled water. If the gravity is below 1.270, draw off some of the electrolyte and replace it with 1.300 electrolyte. If necessary to put in 1.300 electrolyte, allow the battery to continue charging for about one-half hour longer at a rate sufficient to cause gassing, which will cause the stronger acid to become thoroughly mixed with the rest of the electrolyte in the cell.

Overhauling the Battery. As already mentioned, it will be found desirable to overhaul the majority of starter batteries at least once a year. The expense to the car owner will be less than the cost of the frequent attention required by a run-down battery with complete renewal at no distant date, and the service rendered by the battery will be much improved. The best time of year to do this is in the late fall, so that the battery may be at its best during the cold weather. Before undertaking the work, have on hand a complete renewal set of rubber and wood separators as well as sufficient fresh acid of 1.300 specific gravity with which to mix fresh electrolyte. Use the good separators, particularly the rubber ones.

Fig. 391. Reburning Battery Connectors with Soldering Iron
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

Dismounting Cells. Remove the connectors by drilling, heating, or pulling (in the same manner as a wheel is pulled), and loosen the jar covers by heating or running a hot putty knife around their edges so that they may be lifted off. The covers should be washed in hot water and then stacked one on top of the other with heavy weight on them to press them flat. Lift the jars out of the battery box and note whether any of them have been leaking. A cracked jar should of course be replaced. Treat one cell at a time, by pulling the element out of the jar with the aid of the pliers, meanwhile holding the jar with the feet. Lay the element on the bench and spread the plates slightly to permit removing the separators, taking care not to injure the rubber sheets, Fig. 392. Separate the positive group from the negative. If the active material of the negative be swollen beyond the surface of the grid, press it back into position before it has a chance to dry, placing boards of suitable thickness between the plates and carefully squeezing the group between heavy boards in a vise or press, as shown in Fig. 393. Boards of sufficient size and thickness must be used between the plates or breakage will result. Charged negative plates will become hot in a short time when exposed to the air and, in this event, should be allowed to cool before reassembling. Remove any loose particles adhering

Fig. 392. Removing Old Separators from Elements

Fig. 393. Pressing Negative Group

Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania to the positive plates by passing a smooth wood paddle over the surface but *do not wash the positive plates.*

Treating the Plates. If the positive plates show signs of buckling or stripping of the active matter, or if the negative plates have the light spotted appearance indicative of sulphating, it may be necessary to replace them altogether. In case sulphating appears to be the only trouble, the groups should be reassembled in an open jar with distilled water and given a long, slow charge, testing with the hydrometer at frequent intervals to note whether the specific gravity is rising or not. Twenty-four hours or more may be necessary for this charge, and two or three days will be nothing unusual. This charging, of course, is carried on from the lighting mains through a rectifier or a motor-generator, unless direct-current service is available. If it is necessary to prolong the charge over two or three days, and the specific gravity still continues to rise slowly, it may be preferable to replace the plates.

Fig. 394. Wood and Rubber Separator

Reassembling Battery. Wash all the sediment out of the jars, also wash and save the rubber sheets, unless they happen to be broken, but throw away the old wood separators. The rubber sheets should be placed in clean running water for about a quarter of an hour. Reassemble the positive and negative groups with the plates on edge in order to insert the separators. Place a rubber separator against the grooved side of a wood separator, Fig. 394, and insert a positive plate near the center of the element. The rubber sheet must be against the positive plate, and the wood separator against the negative plate. In this manner insert separators in all the spaces, working in both directions from the center. Care must be taken *not to omit a separator as that would short-circuit the cell.*

The separators should be practically flush with the bottoms of the plates to bring their tops against the hold-down below the strap, and must extend to or beyond the side edge of the plates. Grip the element near the bottom to prevent the plates flaring out while placing the element in the jar. Fill the cell to within one-half inch of the top of the jar, using electrolyte of 1.250 specific gravity. If the negative plates show signs of sulphating, but not enough to call for the special treatment mentioned above, use water instead of the electrolyte. After all of the cells have been given the same treatment and reassembled, return them to the battery box in their proper positions, so that the positive of each cell will be connected to the negative of the adjoining cell and connect temporarily by pressing the old connecting straps in place by hand.

Checking the Connections. Put the battery on charge at its finishing rate (usually about 5 amperes) and, after charging about fifteen minutes, note the voltage of each cell. This is to insure having reconnected the cells properly with regard to their polarity. If this be the case, they should all read approximately 2 volts. Any cell that reads less is likely to have been connected backward. When the cells begin to gas freely and uniformly, take a hydrometer reading of each cell and a temperature reading of one of them. Reduce the current to one-half the finishing rate. Should the temperature of the electrolyte reach 100° F., reduce the charge, or interrupt it temporarily, to prevent the cells getting any hotter. Both hydrometer and temperature readings must be taken at regular intervals, say four to six hours apart, to determine if the specific gravity is still rising or if it has reached its maximum. Continue the charge and the readings until there has been no further rise for a period of at least twelve hours. Maintain the height of the electrolyte constant by adding water after each reading. (If water were added before the reading, it would not have time to mix with the electrolyte, and the reading would not be correct.)

Should the specific gravity rise to about 1.300 in any cell, draw off the electrolyte down to the level of the tops of the plates and refill with as much water as possible without overflowing. Continue the charge, and if the specific gravity again exceeds 1.300, dump out all the electrolyte in that cell, replace it with water, and continue the charge. The charge can be considered complete only when there has been no rise in the gravity of any of the cells during a period of at least twelve hours of continuous charging. Upon completion of the charge, the electrolyte should have its specific gravity adjusted to its proper value (1.270 to 1.280) using water or 1.300 acid, as may be necessary, and the level of the electrolyte adjusted to a uniform ½ inch above the plates.

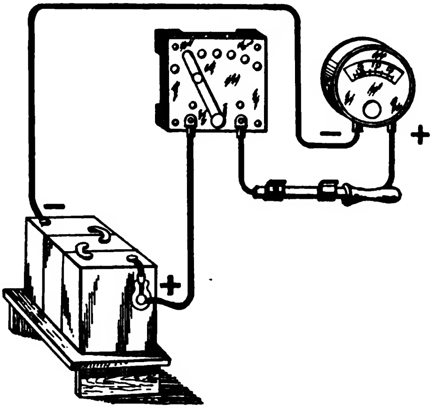


Fig. 395. Wiring Diagram for Discharging Battery through Rheostat

Discharge the battery at its normal discharge rate to determine if there are any low cells caused by defective assembly. The normal discharge rate of the battery is usually given on its name plate. To discharge the battery, the current may be passed through a rheostat, as in Fig. 395, or if no panel board of this type be available, through a water resistance, as shown in Fig. 396. The resistance of a water rheostat increases with the distance between its plates and decreases according to their proximity and to the degree of conductivity of the water itself. If the resistance is too high with the plates close together, add a little acid to the water. It will be necessary, of course, to have an ammeter in the circuit to show the rate at which the battery is discharging. In case any of the cells are low, owing to being assembled defectively or connected with their polarity reversed, as shown

Fig. 396. Wiring Diagram for Discharging Battery through Water Resistance

by the voltmeter test (they should all register two volts or slightly over at the beginning of the discharge and should fall off slowly) such cells should be remedied at once. Recharge the battery and then remove the temporary connectors, wipe the inside edges of the jars dry, and put the rubber covers in place. Heat the sealing compound which is supplied for this purpose and apply around the edges of the covers, smoothing it down with a hot putty knife. Care must be taken not to burn the sealing compound when heating it.

Reconnecting Cells. If the old lead connecting straps have been removed carefully, they may be used again, though in many cases it will be found preferable to employ new straps. Before putting the straps in place, scrape the posts clean with a knife and clean out the eyes of the straps themselves. When the connectors have been put in place, tap them down firmly to insure good contact. Before reburning the connectors in place, test each cell with a low-reading voltmeter to make certain that the cells have been connected in the right direction, i.e., that their polarity has not been reversed. It is not sufficient to note that the voltage of each cell is correct, i.e., 2 volts per cell or over, but care must be taken also to note that it is in the right direction. With a voltmeter having a needle that moves in both directions from zero, one polarity will be evidenced by the needle moving over the scale to the right of the neutral line, while if the polarity be reversed, the needle will move to the left. One cell having the proper polarity should accordingly be tested and then, to be correct, the remaining cells should cause the needle to move in the same direction and to approximate the same voltage when the instrument leads are held to the same terminals in the same way for each. Where the voltmeter needle can move in but one direction, i.e., to the right, a change of polarity will be indicated by the needle of the instrument attempting to move to the left and, in so doing, butting up against the stop provided to prevent this. Complete the reassembly of the cells by burning the connectors together, as detailed under the head of Lead Burning.

Renewals. In many cases it will be found necessary upon overhauling a battery to renew the elements. These may be purchased either as loose plates or as groups ready to assemble in the battery. Except in garages doing a large amount of this work, it will not be advisable to buy the loose plates and burn them into groups.

The new groups should be assembled with rubber sheets and wood separators, as directed in overhauling the battery, the jars filled with fresh electrolyte of the proper specific gravity and the battery given a test charge and discharge with temporary connections. The electrolyte should be of 1.250 specific gravity, or seven parts of water to two of pure sulphuric acid by volume. If the test charge has been carried to a point where the specific gravity has ceased to rise for several hours, and the discharge shows no defectively assembled cells, the cells may be permanently connected.

Lead Burning. *Type of Outfit.* In the manufacture of storage batteries, and in garages where a large number of batteries are maintained, a hydrogen-gas apparatus is employed for this purpose. For the electric-car owner or the garage doing a comparatively small amount of battery repair work, the Electric Storage Battery Company has placed an arc lead-burning outfit on the market. This is low in first cost and, with a little practice, good results can be obtained with it. As the battery itself supplies the power necessary, the only material required is the lead in the form of a flexible strip or heavy wire. The complete outfit is illustrated in Fig. 397. At one end is the clamp for making electrical connection, while at the other is a clamp of different form having an insulated handle and holding a one-fourth inch carbon rod. The two are electrically

Fig. 397. Arc-Welding Outfit for Burning Connections

connected by a flexible cable. This simple outfit can be employed in two ways, the second being preferable for the beginner, at least until sufficient amount of skill has been acquired to use the arc without danger of melting the straps.

First Method of Burning. In the first method, a potential of from 28 to 30 volts (12 to 15 cells) is required.* The clamp should, therefore, be fastened to the positive pole of the twelfth to the fifteenth cell away from the joint to be burned, counting toward the negative terminal of the battery. The carbon then forms the negative terminal of the circuit. Otherwise particles of carbon will be carried into the joint, as the carbon rod quickly disintegrates when it forms the positive pole. The carbon should project 3 or 4 inches from the holder. The surfaces of the parts to be burned should be scraped clean and bright, and small pieces of clean lead about ¼ to ½ inch square provided for filling the joint. The carbon is then touched to the strap to be burned and immediately withdrawn, forming an electric arc which melts the lead very rapidly. By moving the carbon back and forth the arc is made to travel over the joint as desired, the small pieces of lead being dropped in to fill the gap as required. Owing to the high temperature generated, the work must be carried out very quickly, otherwise the whole strap is liable to melt and run.

As this method is difficult and requires practice to secure good results, the beginner should try his hand on some scrap pieces of lead before attempting to operate on a cell. Its advantages are that when properly carried out it takes but a short time to do the work, and the result is a neat and workmanlike joint. It is extremely hard on the eyes and smoked or colored glasses must be used.

Second Method of Burning. The second method, utilizing the hot point of the carbon rod instead of the arc, is recommended for general practice. Scrape the parts to be joined and connect the clamp between the third and fourth cells from the joint. With this method it is not necessary to determine the polarity of the carbon. The latter is simply touched to the joint and held there; on account of the heavy flow of current it rapidly becomes red and then white hot. By moving it around and always keeping it in contact with the metal, the joint can be puddled. To supply lead to fill the joint,

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*This voltage may be obtained from an electric vehicle battery in the garage or from the lighting mains through a suitable resistance, first converting to direct current where the supply is alternating.

an ordinary lead-burning strip can be used, simply introducing the end into the puddle of molten lead, touching the hot carbon. The carbon projecting out of the holder should be only one inch, or even less, in length. After the joint has been made, it can be smoothed off by running the carbon over it a second time.

Use of Forms to Cover Joint. In joining a strap which has been cut in the center, it is best to make a form around the strap by means of a piece of asbestos sheeting soaked in water and fastened around the strap in the shape of a cup, which will prevent the lead from running down. It will be found that sheet asbestos paper is thick enough, but it should be fairly wet when applied. By this means a neat joint can be easily made. The asbestos will adhere very tightly to the metal owing to the heat, but can be removed by wetting it again. When burning a pillar post to a strap, a form may be made around the end of the strap in the same manner, though this is not necessary if reasonable care is used. Two or three pieces of $\frac{1}{16}$-inch strap iron about one inch wide, and some iron nuts about one inch square are also of service in making the joint, the strap iron to be used under the joints, and the nuts at the side or ends to confine the molten lead. Clay can also be used in place of asbestos, wetting it to a stiff paste. As the holder is liable to become so hot from constant use as to damage the insulation, besides making it uncomfortable to hold, a pail of water should be handy, and the carbon dipped into it from time to time. This will not affect its operation in any way, as the carbon becomes hot again immediately the current passes through it.

Illuminating Gas Outfit. Heretofore it has not been possible to do good work in lead burning with illuminating gas, but a special type of burner has recently been perfected by the Electric Storage Battery Company, which permits the use of illuminating gas with satisfactory results. The outfit consists of a special burning tip and mixing valve. Sufficient $\frac{5}{16}$-inch rubber hose should be provided, and the rubber should be wired firmly to the corrugated connections, Fig. 398, as the air is used at a comparatively high pressure. A supply of compressed air is necessary, the proper pressure ranging from 5 to 10 pounds, depending upon the length of hose and the size of the parts to be burned. When air from a compressor used for pumping tires is utilized for this purpose, a suitable reducing valve must be introduced in the supply line. This outfit is designed for use with ordinary illuminating gas and cannot be employed with natural gas.

Connect the air hose to the right-hand cock and the gas hose to the left-hand cock. The leader hose, about five or six feet long, is connected to the lower pipe and to the upper end of the burning tip. When the air pressure at the source is properly adjusted, close the air cock and turn the gas cock on full. Light the gas at the tip and turn on the air. If the flame blows out, reduce the air pressure, preferably at the source. With the gas turned on full, the flame will have a ragged appearance and show a waist about ½ inch from the end of the tip, the flame converging there and spreading out beyond. Such a flame is not good for lead burning.

Fig. 398. Lead-Burning Outfit for Use with Illuminating Gas
Courtesy of Electric Storage Battery Company,
Philadelphia, Pennsylvania

Slowly turn the gas off until the outer portion at the waist breaks and spreads with an inner tongue of flame issuing through the outer ring. The flame will now have a greenish color and is properly adjusted for burning. If the gas is turned off further or if too much air is turned on, the flame assumes a blue color gradually becoming invisible and is then deficient in heating power. When properly adjusted, the hottest part of the flame is just past the end of the inner point. Do not hold the flame too close to the work when burning, as its heating effect is greatly reduced and the flame is spread so as to make control difficult. The burning tip has at its lower end an outer sleeve and lock nut; this sleeve can be taken off in case any of the holes in the tip become clogged. The position of this sleeve is adjustable, the best position varying with the pressure of the flame, and it should be determined by experiment.

Hydrogen Gas Outfit. Hydrogen gas gives a hotter flame and therefore permits of more rapid work, so that where burning is done on a large scale, it is still preferred. The essentials of such an outfit are: first, a hydrogen generator; second, a method of producing air pressure at approximately 2 pounds to the square inch; and third, the usual pipe and tips for burning. If hydrogen gas is purchased in a tank and compressed air is available, only the blowpipe, tips, and a reducing valve on the air line are necessary. This is an expensive method to purchase hydrogen, however, so that it is usually generated, and a water bottle is needed between the generator and the blowpipe to wash the gas and to prevent the flame from traveling back to the generator.

For this purpose hydrogen gas is generated by placing zinc in a sulphuric-acid solution. The generator usually employed for vehicle-battery burning requires 50 pounds of zinc, 2 gallons of sulphuric acid, and 9 gallons of water for a charge. Where no compressed-air supply is available, an air pump and an air tank for equalizing the pressure must be used. An outfit of this kind is shown in Fig. 399. In preparing the generator for use, connect up as shown in this cut, taking care that the hose from the generator is connected to the nipple of the water bottle *L*. Have the water bottle one-half to two-thirds full and immerse it in a pail of cold water up to its neck. Replace the water in the pail whenever it becomes warm. Have stop cock *N* closed. Put the required amount of zinc, which has been broken into pieces small enough to pass through the opening *C*, into the lower reservoir. Put on cap *X* and screw down with clamp *D*, being sure that the rubber drainage stopper *H* is well secured in place. Pour the proper amount of water into reservoir *A* and then pour in the acid, taking care to avoid splashing. *Always pour the water in first.*

In running the hose from *K* to *N*, arrange it so that there will be no low points for the water of condensation to collect in; in other words, this hose should drain back at every point to the water bottle. If, however, water should collect in the hose to such an extent as to interfere with the flame and it cannot readily be drained off, kink the hose between *T* and *U* and detach it from *K;* close the stop cock at *W* and pump until a strong pressure is obtained in the tank; then close the cock at *V*, opening those at *S* and *N* and, finally, quickly open *W;* the pressure in the air tank will then force the water out of the hose. The length of the hose from *T* to *U* should be such that the mixing cocks at *S* and *N* are always within easy reach of the man handling the flame.

Fig. 393. **Diagram of Lead-Burning Outfit, Using Hydrogen Gas**

In preparing the flame for burning, close the air cock at *S* and open *N* wide, hold a match to the gas until it lights, then add air and adjust the gas cock slowly, turning toward the closed position until the flame, when tried on a piece of lead, melts the metal and leaves a clean surface. The tip to be used depends on the work, but most vehicle-battery work is done with the medium tip. Replenish the zinc every few days, keeping it up to the required amount. When a charge is exhausted or the generator is to be laid up for the night, the old solution should be drawn off before making up a new charge and the generator thoroughly flushed out by running water through *A*. The new charge should not be put in until the generator is to be used again. To empty the generator, first pull off the hose at the nipple *K*, then at *E*, and finally the rubber plug at *H*. Care shou'd be taken not to allow the solution to splash on anything and not to dump the generator where the contents will damage cement, asphalt, or wood walks.

Installing New Battery. In not a few instances, it will be necessary to renew the entire battery. As received from the manufacturer, the battery is in a charged condition, i.e., it was fully charged just previous to being shipped, but it must be inspected and tested before being installed on the car. Care must be taken in unpacking it to avoid spilling any of the electrolyte. After cleaning off the packing from the tops of the cells, take out the rubber plugs and see that the electrolyte is ½ inch over the plates. If it is uniformly or approximately below the proper level in all the cells, this is simply the loss due to evaporation. But if low in only one or two cells, this is evidently caused by loss of electrolyte. In case this loss has resulted from the case being turned over in shipment, it will be indicated by the presence of acid on the packing on top of the battery (the acid does not evaporate), and some of the electrolyte will have been lost from all the cells. Replace the amount lost by refilling the cells with electrolyte of 1.250 specific gravity, as already directed.

In case the loss of electrolyte is caused by a cracked or broken jar, the packing under the battery will be wet. Replace the broken jar as instructed in the directions under that heading and add sufficient electrolyte of 1.250 specific gravity to make up for the loss. Should it be found, after replacing the broken jar and giving the battery an equalizing charge, that the specific gravity does not reach approximately 1.275, it is due to not having replaced the same amount of acid as was spilled. To adjust this, draw off the electrolyte from the cell with the syringe and add water or 1.300 acid to bring the specific gravity to between 1.270 and 1.280.

Storing a Battery. There is an amusingly erroneous idea prevalent to some extent that the charge of a storage battery is represented by its electrolyte; that pouring off the electrolyte takes the charge with it; that, in case it is desired to store a battery, all that is necessary is to pour off the electrolyte and store the empty battery and the solution separately; and when it is desired to put the battery back in commission, it is then only necessary to pour the electrolyte back into the cells and, presto! they are ready to start the engine right away. Unfortunately for this theory, the charge is in the active material of the plates and not in the electrolyte.

It is frequently necessary to allow the battery to remain idle for a considerable length of time, in which case it should be put out of commission. If the battery itself is in good condition at the time and if it may be wanted for service again at short notice, this need only consist of giving it a long equalizing charge until the specific gravity has ceased to rise for several hours, then filling the cells to the top with distilled water and putting the battery away in a handy place. It should be given a freshening charge every two weeks or, at least, as often as once a month. If it is actually to be stored, there are two ways of doing this.

One is known as the wet storage method, and the other as the dry, the one to be adopted depending upon the condition of the battery and the length of time it is to be out of commission. The wet storage method is usually applied to any battery that is to be out of commission less than a year, provided that it will not soon require repairs necessitating dismantling it. The dry storage method is used for any battery that is to be out of commission for more than a year, regardless of its condition, and it is also applied to any battery that will shortly require repairs necessitating its dismantling. It will be apparent that this last-named class includes most starter batteries after they have seen several months of service, so that the majority can be placed in dry storage when necessary to put them out of commission.

Examine the condition of the plates and the separators and also the amount of sediment in the bottom of the jars. If it is found that there is very little sediment and the plates and separators are in sufficiently good condition to give considerable additional service, the battery may be put into wet storage by giving it an equalizing charge and covering it to exclude dust. Replace evaporation periodically to maintain the level of the electrolyte $\frac{1}{2}$ inch above the

PLATE 113—MOON WIRING DIAGRAM OF 1914 MODEL 42, DELCO SYSTEM (INTERNAL)

PLATE 114—MOON WIRING DIAGRAM OF 1914 MODEL 42, DELCO SYSTEM

PLATE 116—MOON WIRING DIAGRAM OF 1914 MODEL 6-50, DELCO SYSTEM

PLATE 116—MOON WIRING DIAGRAM OF 1915 MODEL 4-38, DELCO SYSTEM

PLATE 117—MOON WIRING DIAGRAM OF 1916 MODELS 6-50, 6-40, DELCO SYSTEM

PLATE 116—NASH WIRING DIAGRAM OF 1919 MODELS 681, 682, DELCO SYSTEM

PLATE 119—NASH

PLATE 120—NASH WIRING DIAGRAM OF TRUCK MODEL, DELCO SYSTEM

PLATE 121—NATIONAL WIRING DIAGRAM OF 1918 MODEL AF3, DELCO SYSTEM

PLATE 122—NATIONAL WIRING DIAGRAM OF 1920 SERIES BB, SERIAL 60001 AND UP, WESTINGHOUSE SYSTEM

PLATE 124—OAKLAND WIRING DIAGRAM OF 1914 MODELS 43-62, DELCO SYSTEM

PLATE 126—OAKLAND WIRING DIAGRAM OF 1914 MODELS 48-62, 43, DELCO SYSTEM

PLATE 127—OAKLAND WIRING DIAGRAM OF 1915 MODEL 37, DELCO SYSTEM

PLATE 128—OAKLAND WIRING DIAGRAM OF 1916 MODEL 49, DELCO SYSTEM

tops of the plates. At least once every four months, charge the battery at one-half its normal finishing rate (see name plate on battery box) until all the cells have gassed continuously for at least three hours. Any cells not gassing should be examined, and the trouble remedied.

When examination shows that the battery will soon require dismantling, it should be put into dry storage. Dismantle the cells in accordance with the instructions already given. If the positive plates show much wear, they should be scrapped; if not, remove any loose particles adhering to them by passing a smooth wood paddle over the surface, but *do not wash the positive plates.* Charged negative plates will become hot in a short time when exposed to the air. They should be allowed to stand in the air until cooled.

Empty all the electrolyte out of the jars into a glass or glazed earthenware jar or a lead-lined tank and save it for giving the negative plates their final treatment before storage. Wash all the sediment out of the jars and wash the rubber separators carefully, then dry them and tie them in bundles. Place the positive groups together in pairs, put them in the jars, and store them away. Then put the negative groups together in the same way, place them in the remaining jars, and cover them with the electrolyte saved for the purpose, allowing them to stand in it for five hours, at least. Then pour off the electrolyte, which may now be discarded, and store away the jars containing the negatives. If the negative plates show any bulging of the active material, they should be subjected to the pressing treatment first, using boards and a vise, as described in a previous section. All of the jars should be well covered to exclude dust.

Make a memorandum of the amount of material required to reassemble the battery, and, when ordering this, provide for extra jars and covers, extra rubber separators, and an entire lot of wood separators with a sufficient excess to take care of breakage in handling. Unless the old connectors were carefully removed, order a new set. When a battery is put in storage, it is well to advise the owner in regard to the material necessary to reassemble, and to request at least a month's notice to procure it.

Charging from Outside Source. Theoretically at least, the starter battery on the automobile should be kept in an ideal condition. It is constantly under charge while the car is running at anything except the lowest starting speeds and should accordingly always be fully charged. The generator is designed to take care of the storage battery and usually has sufficient capacity to light all the lamps in addition. Practice, however, does not bear out this theoretical view of the favorable conditions under which the starter battery is supposed to operate. It will be apparent at the very outset that the method of charging and discharging is not beneficial. To insure long life to a storage battery, it should be fully charged and then discharged to at least seventy-five per cent of its maximum capacity before recharging. It should never be allowed to stand discharged for any length of time. If exhausted, it should be recharged immediately. It should not be charged to half its capacity and then discharged. It should not be overcharged to the point where it continues to gas violently nor where its temperature exceeds 100° F.

All of these are things that should not be done to the storage battery, but it will take only a little experience to enable the garage man to recognize that all these are things which are constantly being done to the majority of storage batteries on gasoline automobiles. Most batteries receive treatment that reaches one extreme or the other, though it will be apparent that the middle course is almost as injurious to the battery. Either a battery is constantly kept undercharged so that it has insufficient charge to spin the engine more than once, and its operation is accordingly unsatisfactory, or it is constantly kept overcharged with the result that the hot acid makes comparatively short work of the plates, and they must be renewed in considerably less than a year of service. The mean course between these two is found in the case of the battery that is only charged to about half its capacity before being discharged again by the use of the starting motor. This treatment results in sulphating.

To keep the storage battery of the starting system in anything like efficient operating condition, it cannot be left on the running board with nothing but the generator of the starting and lighting system to charge it. Hydrometer and voltage tests will be valueless unless the conditions they indicate are remedied, and this cannot be done with the car generator as the sole source of charging current. Here is a typical instance: The battery is in good condition and it is fully charged. On a cold morning, it is drawn on intermittently for almost fifteen minutes by the starting motor before the engine fires. As a result, it is practically discharged. The car is driven only a few miles, stopped and after a rest started again. What charge the battery received by the short run is again lost. The car is run for a little longer time and returned to the garage. The battery has received about one-fourth its normal charge. It stands this way for several days.

The weather being warmer, the engine starts in a much shorter time, but not before the starting motor has exhausted the small amount of charge in the battery. It is not run enough that day to charge the battery nor when taken out again that night, as all the lights are switched on, and under such conditions the battery receives very little current. Multiply this treatment by five or ten representing the number of days the car is driven during the month. At the end of that time, the battery no longer has sufficient charge to operate the starting motor at all and is condemned, as usual, by the car owner as being worthless. This is only one instance of many that are so similar that a few changes in detail would cover them all. No battery ever made could possibly operate efficiently under such conditions. After the car in question had been used a few days, a hydrometer test of the battery would have indicated its need of charging.

Equalizing Charges Necessary. Even where a battery receives almost 100 per cent of its normal charge before being discharged again, there will be numerous occasions on which the charge is not carried to completion. As mentioned under the head of Sulphating, that means so much acid left in the plates at the end of the charge. That acid represents lead sulphate which continues to increase in quantity as long as the acid remains in contact with the active material. To drive it out of the active material into the electrolyte, which is the function of charging, the charge must be carried to completion. This is termed an equalizing charge, and it should be given not oftener than once in two weeks, but at least once a month. To do this, it is necessary to charge the battery from an outside source, as it is seldom convenient to run the engine for the long period of time needed to complete such a charge. Except in cases where the battery is chronically overcharged, as indicated by its violent and continued gassing, it will usually be found necessary to give it an equalizing charge once a month. The constantly overcharged condition is quite as injurious as its opposite, and it can be cured only by cutting down the output of the generator or increasing the demand upon the battery for current.

Methods of Charging. The apparatus employed for charging starter batteries will naturally vary in accordance with the number that are looked after in the garage. It may range from the makeshift consisting of a bank of lamps up to an elaborate panel board designed to provide charging connections for a dozen or more batteries at once. Where direct current is available—and only a few starter batteries need this attention—a bank of lamps in connection with a fused double-pole switch will be found to fill all the requirements. Note the charging rate (finishing) given on the name plate of the battery and make the number of lamps in accordance. A 32 c.p. in the circuit is practically the equivalent of one ampere of current entering the battery, i.e., it requires one ampere to light a lamp of this size and type (carbon filament) to incandescence. A number of standard lamp sockets should be mounted on a board, connected in multiple, and the group connected in series with the switch and the battery. (See illustration in résumé of questions and answers on the battery.) As many lamps as necessary may then be screwed into the sockets. The more current needed, the more lamps and the higher power lamps will be necessary. Tungsten lamps may be employed as well as the carbon-filament type, but as they take so much less current, lamps of higher candle power will be needed. For example, to replace a 32-c.p. carbon-filament lamp, a 100-watt tungsten lamp will be required.

Charging in Series for Economy. Where several starter batteries are to be charged at the same time, it will be found more economical to connect them in series and charge them all at once. The difference between the 110-volt potential of the lighting mains and the 6 to 8 volts needed to charge a single three-cell battery represents that much waste, as the drop in voltage has to be dissipated, through a resistance, to no purpose. In this way, any number of 6-volt storage batteries, up to twelve, can be charged from a 110-volt circuit (direct-current) with the same expenditure of current as would be required for a single battery. This is owing to the fact that, in any storage battery, the capacity of the battery is the capacity of one cell, where all are connected in series. Consequently, it will take 10 to 15 amperes to charge one 6-volt battery from the lighting circuit, and when several more units of the same size are connected in series with it, the current consumption will still be the same, but a smaller part of the voltage will have to be wasted through a resistance.

Motor-Generator. Direct current will be found available in comparatively few places to-day, so that some means of rectifying an alternating current, in order to use it for charging batteries, will be necessary. Where quite a number of batteries are to be cared for, the motor-generator will be found to give the highest efficiency, besides proving more economical in other ways. As its name indicates, it consists of a motor wound for alternating current and fed from the supply mains of the garage, and a direct-current generator which is driven at its normal generating speed by the a.c. motor. There is no electrical connection between the two units. Electrical power in the form of an alternating current is converted into mechanical power in the a.c. motor which drives the armature of the d.c. generator and again converts it into electrical power in the form of a direct current. The first cost of a motor-generator is such that its use is usually confined to large establishments handling quite a number of batteries, though motor generators are now made in much smaller sizes than formerly.

A.C. Rectifiers. Where the amount of charging to be done does not warrant the investment in a motor-generator, a rectifier is usually employed. There are several makes of different types on the market: the chemical type, which employs lead and aluminum plates in an acid solution; the mercury-arc type, in which mercury is vaporized in a vacuum by the passage of the current; and others, in all of which the principle is the same. This consists in utilizing the current on but one part of the wave, so that the efficiency of these rectifiers ranges from 60 to 75 per cent. It is accordingly not good practice to employ them except in the smaller sizes. While the mercury-vapor rectifier is made for charging private vehicle batteries, the other types are ordinarily confined to sizes intended for charging small batteries.

A recent addition to the list that is available for this purpose is the Tungar rectifier, made by the General Electric Company. The principle on which this works is the same, but the medium is a new one. This is a bulb exhausted of air and filled with a special gas in which a heavy tungsten-wire filament is brought to incandescence by the passage of the alternating current. This filament is very short and thick, its diameter depending upon the capacity of the rectifier, and it is placed horizontally. It constitutes the cathode of the couple. Directly opposite it, but a short distance away, is the anode of graphite in the form of a button, the lower face of which is presented to the tungsten wire. It is made in three sizes, the smallest of which has a capacity of but 2 amperes and is designed for charging the batteries of small portable lamps, such as are used by miners; and for charging ignition, call bell, burglar alarm batteries, and the like.

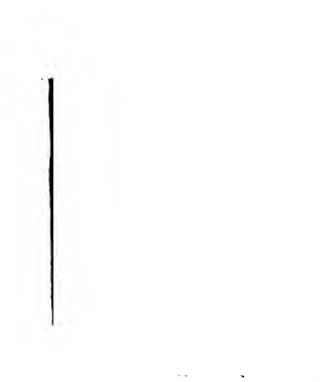

Fig. 400. Front View of Large Size G. E. Tungar Rectifier

In the larger size, as shown in Fig. 400, the bulb is mounted in an iron case, on the face of which are mounted the switch for alternating current; an ammeter on the d.c. side, showing the charge received by the battery; and a dial switch for adjusting the voltage to the number of batteries to be charged. There is a compensator with 15 taps, and the current is adjustable by steps up to 6 amperes. Anything from a single three-cell battery up to ten of such units (30 cells in all) may be charged at once. The batteries must be connected in series and then it is only necessary to turn the switch of the a.c. circuit. In case the alternating-current supply should fail, the battery cannot discharge through the rectifier, and the latter

Fig. 401. Interior View of Small Size G. E. Tungar Rectifier
Courtesy of General Electric Company, Schenectady, New York

will assume its task again automatically as soon as the current comes on. This is the 6-ampere 75-volt size. It is also made in a 6-ampere 15-volt size designed for the charging of a three- or six-cell starter battery in the home garage. Fig. 401 shows an interior view of this size, illustrating the position of the converting bulb, the compensator, the reactance coil, and the fuses, while Fig. 402 illustrates the 6-ampere 75-volt size, showing the panel instrument, i.e., switch, ammeter, and regulating handle, as well as the bulb and fuses. A closer view of the bulb itself is shown in Fig. 403.

Fig. 402. Interior View of Large Size G.E. Tungar Rectifier

Care of Battery in Winter. There is a more or less general impression that special treatment must be given the storage battery during cold weather. This is probably owing to the fact that lack of attention makes itself apparent much more readily in winter than in summer because of the lower efficiency of the battery resulting from the lower temperature. The care necessary in winter does not vary in any respect from that which should be given in warm weather, except possibly that replacement of the water due to evaporation is not called for so often, but unless it is conscientiously carried out, the battery is apt to suffer to a greater extent. In speaking of low temperatures, it must be borne in mind that this always refers to the temperature of the electrolyte of the battery, and not to that of the surrounding atmosphere. The latter may be considerably below freezing, whereas the liquid in the cells may be approaching 100° F. when the battery is under charge.

Fig. 403. Tungar Rectifying Bulb—the Heart of the Rectifier

Make the usual hydrometer and voltage tests, as described under the headings in question, and see that the battery is constantly kept more fully charged than would be necessary to render satisfactory service in warmer weather. This is important for two reasons: first, because of the greatly increased drain on the battery owing to the difficulty of starting the engine when cold; and second, because of the liability of the electrolyte to freeze if the battery is allowed to stand discharged in very cold weather. There is not the same excess supply of current available for charging the battery in winter as there is in summer, as the lights are in use during a much greater part of the time and not so much driving is likely to be done during the day. As the lamp load consumes almost the entire output of the generator in the average starting and lighting system, there is very little left for the battery when all the lamps are in use. The practice of turning on all the lights on the car—headlights, side lights spot light, and instrument lights—whether they are necessary or not, should be discouraged in winter, as it is likely to result in exhausting the battery. The instrument lights are usually in series with the tail light, and so cannot be dispensed with, but it is never necessary to have the headlights and side lights going at the same time, and this also applies to the spot light, which consumes almost as much current as one of the headlights and should be restricted to the use for which it is intended, i.e., reading signs by the roadside.

Unless the lamp load is reduced, it may be necessary to increase the charging rate of the generator during the cold months, and this is not beneficial to the battery, as it may cause severe gassing and injury to the plates when continued too long. In case the car is not driven enough to keep the battery properly charged, it may be necessary to charge it from an outside source or, if the latter be not available, to run the engine with the car idle just for this purpose. Care must be taken to prevent any danger of freezing, and the best method of doing this is to keep the battery fully charged, as when in this condition it will freeze only at very low temperatures. The more nearly discharged a battery is, the higher the temperature at which it will freeze, and freezing will ruin the cells, regardless of whether it happens to crack the jars or not.

Why Starting Is Harder in Cold Weather. The electric starting and lighting system, or rather the storage battery, which is its main-stay, is much more severely taxed in winter than in summer for the following four reasons:

(1) The efficiency of the storage battery decreases with a decrease in temperature, because the action of the storage battery is chemical, and chemical action is dependent upon heat and, therefore, always decreases as the temperature decreases.

(2) The lower the temperature the stiffer the lubricating oil, which gums the moving parts together, adding a very considerable load to the ordinary amount of inertia which the starting motor must overcome and likewise adding to the difficulty of turning the engine past compression.

(3) Gasoline will not vaporize readily at a low temperature, so that it is necessary to turn the engine over a great many revolutions before the cylinders become sufficiently warmed from the friction and the repeated compression to create an explosive mixture. The better the mixture the more readily it will fire, and consequently a greater heat value is required in the spark to ignite it where the mixture is poor or only partly vaporized. Anything that reduces the efficiency of the storage battery likewise reduces the heat value of the ignition spark.

(4) Low heat value of the spark often makes it difficult to start an engine when cold. This lack of heat in the spark is caused by a partially discharged battery as well as the lower efficiency of the battery caused by the cold weather; also by the necessity for repeated operation of the starting motor, whereby the voltage of the battery is temporarily cut down.

Intermittent use of the starting motor with a brief period between attempts will frequently result in starting a cold engine where continued operation of the starting motor will only result in exhausting the battery to no purpose. The longer the starting motor is operated continuously the lower the voltage of the battery becomes, with a corresponding drop in the heat value of the ignition spark. Cranking intermittently a number of times has practically as great an effect in warming the cylinders and generating an explosive mixture as running for the same period (actual operating time in each case), while the brief periods of rest permit the battery to restore its normal voltage, which increases the heat value of the spark and causes the engine to fire. Both the storage battery and the remaining essentials of the starting and lighting system are designed to give satisfactory service in cold weather, but as a very low temperature brings about conditions representing the maximum for which the system is designed, more skillful handling is necessary in winter than in summer to obtain equally good results.

To Test Rate of Discharge. If the battery terminals are removable, take off either the positive or the negative terminal, and connect the shunt of the ammeter to the terminal post and to the cable which has been removed, binding or wiring it tightly in place to insure good contact. Where the battery terminals are not easily removable, insert the shunt in the first joint in the line, as shown in the illustration, Fig. 404. Then connect the ammeter terminals to the shunt. In case the instrument shows a reverse reading, reverse the connections to the shunt. When the ammeter is connected to test for discharge, the starter must never be used unless the 300-ampere shunt is in circuit, as otherwise the instrument is likely to be damaged. If a shunt of smaller capacity or a self-contained ammeter, i.e., one designed to be connected directly in the line is employed, and it is necessary to start the engine, either crank by hand or disconnect the ammeter before using the starting motor.

Fig. 404. Setup for Testing Rate of Discharge of Small Storage Battery
Courtesy of Prest-O-Lite Company, Indianapolis, Indiana

When the ammeter is connected to show the discharge and no lights are on, the engine being idle, no current is being used for any purpose, and the pointer of the ammeter should remain at zero. If any flow of current (discharge) is indicated, it shows that there is a ground or a short-circuit (a leak) somewhere in the system. In such a case, apply the usual tests described under the appropriate headings for locating grounds and short-circuits.

With the ammeter connected up as shown in the illustration, the discharge rate of the battery under the various loads it is called upon to carry may be checked up, and, if it proves to be excessive in any case, the trouble may be remedied. For example, with the 300-ampere shunt in the line, the amount of energy consumed by the starting motor may be checked. Without knowing how much current a certain make of starting motor should consume in turning over a given type of engine, it will naturally be impossible to make any intelligent comparisons with the result of the tests. This information, however, is readily obtainable from the manufacturer of the starting system, and it will be found advantageous to obtain details of this nature covering the various systems in general use in your locality, as it will enable you to make these tests valuable in correcting faults. While the starting loads imposed on the electric motor by different engines will vary greatly, the general nature of the load will be practically the same in all cases. When the starter switch is closed, there will be an excessive discharge rate from the battery for a few seconds, the discharge falling off very rapidly as the inertia of the engine is overcome and it begins to turn over, with a still greater drop to a comparatively small discharge the moment it takes up its cycle and begins to run under its own power.

Before undertaking such tests, see that the battery is in good condition and fully charged. Make several tests. Note in each case whether the maximum discharge at the moment of closing the switch exceeds the maximum called for by the maker of the starting system. If a great deal more current is necessary to turn the engine over than should be the case, it is an indication either that the starting motor is in need of attention or that the engine itself is unusually stiff. Atmospheric conditions will naturally have a decided effect on the result of such tests, as an engine that has stood overnight in a cold garage will be gummed up with thick lubricating oil and will require more power to move it at first than if it had been running only a few minutes before. As a general rule, more power will always be needed in winter than in summer, unless the tests are carried out in a well-heated garage. The condition of the engine itself will also have an important bearing on the significance of the tests, as, if the engine has been overhauled recently, its main bearings may have been tightened up to a point where the engine as a whole is very stiff.

Note also whether the discharge rate falls off as quickly as it should when the engine begins to turn over rapidly. If it does not, this also is an indication of tight bearings, gummed lubricating oil, or similar causes, rendering the engine harder to turn over. In the case of a cold engine, stiffness due to the lubricating oil may be remedied by running it for ten or fifteen minutes, and a subsequent test should then agree with the manufacturer's rating. Where the discharge rate does not drop to a nominal amperage within a few seconds from the time of closing the switch, it is simply an indication that the essentials of the engine are not in the best of working order. The carburetor may not be working properly, or the ignition may be sluggish.

In case the discharge rate is very much less than that called for by the manufacturer for that particular engine, it is an indication that the starting system itself is not in the best condition. Poor connections, worn brushes, loose brush springs, a dirty switch, or some similar cause is greatly increasing the resistance in the starting circuit, thus cutting down materially the amount of current that the battery can force through it. In such circumstances, the discharge may not reach so high a rate as that called for by the manufacturer, but to effect a start, even with the engine in normally good condition, a high rate will have to be continued longer, to the correspondingly greater detriment of the battery. In other words, a great deal more current must be drawn from the battery each time the engine is started. Thus, testing the rate of discharge may be made to serve as an indication of the condition of both the starting system and the engine itself. Should it be necessary to make more than eight or ten starts to determine definitely the cause of any variation between the discharge rates shown and those that should be indicated, with everything in normally good condition, the battery should be fully recharged before proceeding any further, as using it for this purpose when almost exhausted is very likely to damage it. Tests of this kind show also whether the efficiency of the battery has fallen off substantially or not, as indicated by its condition after making several starts in succession. When this has been done, the battery may be tested with the voltmeter and hydrometer to ascertain how far it has been discharged. The fact that after having been in service for some time a starting system will not start the engine so many times without exhausting the battery as it would when new may be due either to a loss of efficiency in the battery or to the poor condition of the other essentials of the system. In the majority of cases, however, it will be due to the condition of the battery.

By substituting the 30-ampere shunt for the 300-ampere, the load put on the battery by the lights when switched on in various combinations may be checked and compared with the manufacturer's ratings. Where the discharge rate for the lights is less than it should be, it may be due to the use of bulbs which have seen a great deal of service, the resistance of the filaments increasing with age, or other causes which place more resistance in the circuit, such as poor connections, loose or dirty switches, and the like. Tests may also be made of the ignition system where the battery is called upon to supply current to a distributor and coil by putting the 3-ampere shunt in the circuit. The amount of current required by the ignition system is very small when everything is in normal working order, usually not more than 1½ to 2 amperes. This also can be obtained definitely from the maker of the apparatus. Any great increase in the amount of current necessary would usually indicate arcing at the contact points, which should prove to be in poor condition; a subnormal discharge would signify a great increase in the resistance as in the foregoing cases, and should be evidenced by poor ignition service.

To Test Rate of Charge. To determine the rate at which the battery is being charged (the small dash ammeters are only approximately accurate), reverse the ammeter connections and start the engine by hand. If the car is equipped with a straight 6- or 12-volt system and a dash ammeter is used, see that its reading agrees approximately with the portable ammeter. Should the variation be small, advise the owner so that he may correct his readings accordingly when noting the instrument on the road. In case it is very large, the dash ammeter itself should be adjusted, which can frequently be done merely by bending the pointer.

With the engine running fast enough to give the maximum charging rate, which is indicated by the fact that the ammeter needle stops rising, check the charging rate shown on the portable ammeter, bearing the following in mind: In the majority of cars, the generator is regulated to charge the battery at from 10 to 15 amperes. Some are designed to charge at as low a rate as 7 amperes. Unless the proper charging rate is definitely known, whatever maximum the portable ammeter shows may usually be assumed to be correct. Where the rate is less than 7 amperes it may generally be taken for granted, however, that the battery is undercharging, and the various tests, described in detail under appropriate headings, may be applied to locate the trouble either in the generator or in the automatic cut-out. This applies where the charging rate is too high as well as where it is too low.

The charging rates mentioned above naturally apply only to a 6-volt battery, or to a battery having a greater number of cells, which is connected in series multiple so as to charge at 6 volts. In the case of a six-cell battery permanently connected in series so that it both charges and discharges at 12 volts, the above figures must be cut in half. Twelve-cell batteries are employed in some cases, but the total voltage of the battery is used only for starting, the cells being divided into four groups in series multiple so that each group of three cells charges at 6 volts.

With the generator charging at 10 to 15 amperes, turn on all the lights. If more current is being drawn from the battery than is being supplied by the generator, this will be indicated by the ammeter showing a reverse reading or discharge. It signifies that there is a short-circuit in the lighting switch or the lamps, or in the wiring between the switch and the lamps, or that additional lights, other than those furnished originally with the system, have been added, or larger candle-power bulbs substituted, thus placing too great a demand on the battery.

If the system has been out of adjustment for any length of time, it is quite likely that the battery will shortly need repairs or replacement, because charging at an excessive rate causes the plates to buckle and break through the separators, forming an internal short-circuit, while charging at too low a rate causes a constantly discharged condition of the battery, due to more current being normally called for than is put in. This results in injurious sulphating of the plates.

In case additional equipment has been added, the entire equipment should be turned on, and the total current required should be noted when making discharge-rate tests. Where the generator cannot supply sufficient current to permit the battery to take care of this extra equipment, the battery should be charged from an outside source at regular intervals. It is poor practice to increase the charging rate of the generator, as it is likely to injure the battery through overheating. Where it is necessary to have a higher charging rate than that originally called for by the system, it is preferable to substitute a larger battery. The charging rate of the generator may then be safely increased in accordance with the demand.

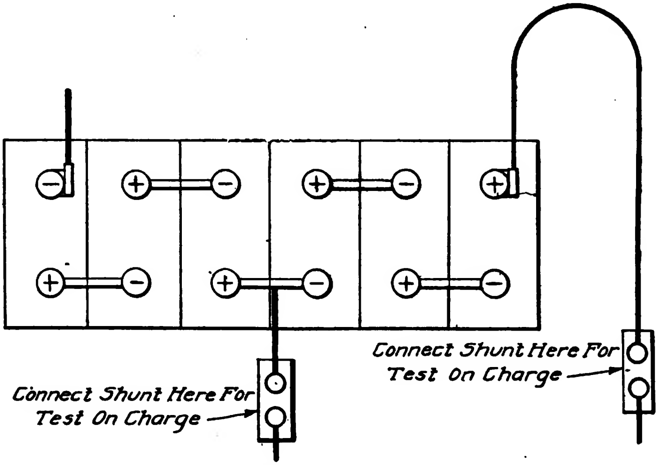

Fig. 405. Setup for Twelve-Volt Battery Wired to Charge and Discharge through Starting Motor at Twelve Volts and through Lamps at Six Volts

In cold weather, it may be necessary to slightly increase the charging rate of the generator in order to compensate for the extra current the battery is called upon to supply. This is owing, not only to the fact that there is a much greater demand on the starting system in cold weather, but also to the fact that the battery is less efficient under winter conditions of operation.

Connections for Two-Voltage Batteries. Where the battery is of either three or six cells, all connected permanently in series, the foregoing suggestions for connecting the testing instruments apply. They must be varied, however, where tests are to be made of batteries connected in series multiple, which may be termed two-voltage batteries since they supply current at one voltage for lighting and at another for starting. In Fig. 405 is shown a battery of this type which is connected so as to charge and discharge through the starting motor at 12 volts, but which discharges at 6 volts to supply the lamps through a neutral lead in the center of the battery. The sketch indicates where to connect the ammeter shunt on charge at 12 volts and on discharge at 6 volts. When testing the starting-motor discharge, it would be connected for 12 volts.

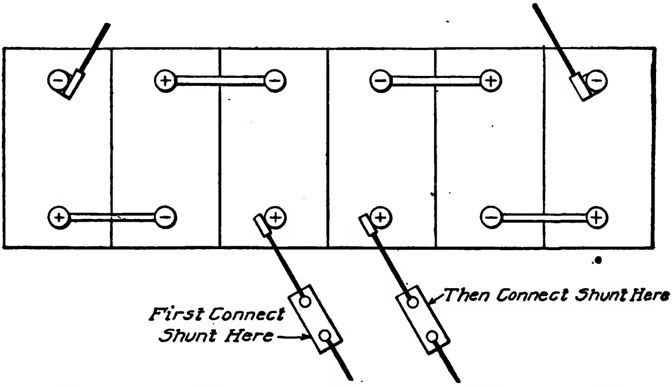

Fig. 406. Twelve-Volt Battery Connected Up to Make Two 6-Volt Batteries in Parallel

Test the 12-volt circuit with the engine running to get the charging rate; stop the engine, reverse the ammeter terminals and see whether there is any discharge indicating a short-circuit. Also test the discharge rate on the 6-volt circuit with the lights turned off and again with all lights on. These tests should show whether or not there is a short-circuit in the system. Before attempting to test the discharge rate of the starting motor, be certain that the 300-ampere shunt is in the circuit. A 12-volt battery will discharge only about half the current necessary to start the engine with a 6-volt battery, but no shunt smaller than the 300-ampere size can be depended upon to carry the load safely and protect the instrument.

PLATE 129—OAKLAND WIRING DIAGRAM OF 1920 MODEL 34-C, DELCO SYSTEM

PLATE 130—OLDSMOBILE WIRING DIAGRAM OF 1913 MODEL 53, DELCO SYSTEM

PLATE 132—OLDSMOBILE WIRING DIAGRAM OF 1915 MODEL 42, DELCO SYSTEM

PLATE 133—OLDSMOBILE WIRING DIAGRAM OF 1915 MODEL 55, DELCO SYSTEM

PLATE 184—OLDSMOBILE WIRING DIAGRAM OF 1917 MODEL 37, REMY SYSTEM

PLATE 135—OLDSMOBILE WIRING DIAGRAM OF 1919 MODEL 45-A, DELCO SYSTEM

PLATE 136—OLDSMOBILE WIRING DIAGRAM OF 1919 MODEL 45-B, DELCO SYSTEM

PLATE 137—OLDSMOBILE WIRING DIAGRAM OF 1920 MODEL 45-B, DELCO SYSTEM

PLATE 138—OLYMPIAN WIRING DIAGRAM OF 1917 MODEL, AUTO-LITE SYSTEM

PLATE [illegible]—PACKARD WIRING DIAGRAM OF [illegible] MODELS [illegible], [illegible], BIJUR SYSTEM

PLATE 141—PACKARD WIRING DIAGRAM OF 1916 TWIN-SIX MODELS, BIJUR SYSTEM

PLATE 142—PACKARD WIRING DIAGRAM OF 1919-20 MODELS 325-335, DELCO LIGHTING AND IGNITION SYSTEMS

PLATE 144—PACKARD WIRING DIAGRAM OF 1920 SINGLE-SIX MODEL, ATWATER-KENT STARTING AND LIGHTING, DELCO IGNITION SYSTEMS

Fig. 406 shows a 12-volt battery connected up in such a manner that it is practically two 6-volt batteries in parallel. The battery is charged at 6 volts, and both the lights and horn are supplied with current at this voltage, but the discharge through the starting motor is at 12 volts. Note the two positive cables leading to the center of the battery. To test the charging rate, the ammeter shunt should be connected first in one of these cables and then in the other, and the two readings added together to obtain the charging rate for the entire battery. The same locations for the shunt, and the same method of adding the readings also apply on discharge. Ammeter readings in the connections shown will indicate whether or not there are any short-circuits, except, of course, in the starting-motor cable.

Voltage Tests. An equally important instrument for the testing of the storage battery is the voltmeter. It is chiefly useful in showing whether a cell is short-circuited or otherwise in bad condition. Under some conditions, it indicates when the battery is practically discharged, but, like the hydrometer, it must not be relied upon alone. It should be used in conjunction with the hydrometer readings to insure accuracy. Since a variation as low as .1 (one-tenth) of a volt makes considerable difference in what the reading indicates as to the condition of the battery, it will be apparent that a cheap and inaccurate voltmeter is likely to be misleading rather than helpful. For garage use, a good reliable instrument with several connections for giving a variable range of readings should be employed. Instructions furnished with the instrument give in detail the method of using the various connections, and these instructions should be followed closely, as otherwise the voltmeter is likely to be damaged. For example, on the 3-volt scale only one cell should be tested. Attempting to test any more is likely to burn out the 3-volt coil in the meter. The total voltage of the number of cells tested must never exceed the reading of the particular scale being used at the time, as otherwise the instrument will be ruined.

Always make certain that the place on the connector selected for the contact of the testing point is clean and bright and that the contact is firm, as otherwise the reading will be misleading, since the increased resistance of a poor contact will cut down the voltage. The positive terminal of the voltmeter must be brought in contact with the positive terminal of the battery, and the negative terminal of the voltmeter with the negative terminal of the battery. If the markings of the cell terminals are indistinct, the proper terminals may be determined by connecting the voltmeter across any one cell. Should the pointer not give any voltage reading, butting up against the stop at the left instead, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive of the cell. This test can be made with a voltmeter without any risk of short-circuiting the cell, since the voltmeter is wound to a high resistance and will pass very little current. This is not the case with an ammeter, however, as connecting such an instrument directly across the terminals of the battery will immediately burn out the ammeter.

Fig. 407. Proper Setup for Testing Voltage of Batteries

Inasmuch as any cell, when idle, will show approximately 2 volts, regardless of whether it is fully charged or not, voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are practically valueless, *except when a cell is out of order*. Therefore, a load, such as switching on the lamps, should be put on the battery before making voltage tests. With the lights on, connect the voltmeter as explained above and test the individual cells, Fig. 407 (Prest-O-Lite). If the battery is in good condition, the voltage readings after the load has been on for about five minutes will be but slightly lower (about one-tenth of a volt) than if the battery were on open circuit. If any of the cells are completely discharged, the voltage of these cells will drop rapidly when the load is first put on and, sometimes when a cell is out of order, even show reverse readings. Where the battery is nearly discharged, the voltage of each cell will be considerably lower than if the battery were on open circuit after the load has been on for five minutes. In the case of an electric-vehicle battery, the lights alone would not provide sufficient load for making an accurate test, so that one of the rear wheels may be jacked up and the brake set lightly until the ammeter on the dash of the car shows 50 to 70 per cent of the usual normal reading. To do this, start the motor on first speed with the brakes loose, and apply the brakes slowly until the desired load is shown by the ammeter reading. Never, under any circumstances, attempt to start with the brakes locked or on hard, as both the battery and the motor will be damaged. In the case of a starting-system battery, the lights alone are sufficient load, as they consume about 10 amperes.

To distinguish the difference between cells that are merely discharged and those that are out of order, put the battery on charge (crank the engine by hand in the case of a starter battery) and test again with the voltmeter. If the voltage does not rise to approximately 2 volts per cell within a short time, it is evidence of internal trouble which can be remedied only by dismantling the cell.

Temperature Variations in Voltage. It must be considered, in making voltage tests, that the voltage of a cold battery rises slightly above normal on discharge. The reverse is true of a really warm battery in hot weather, i.e., it will be slightly less than normal on charge and higher than normal on discharge. As explained in connection with hydrometer tests of the electrolyte, the normal temperature of the electrolyte may be regarded as 70° F., but this refers only to the temperature of the liquid itself as shown by a battery thermometer, and not to the temperature of the surrounding air. For the purposes of simple tests for condition, voltage readings on discharge are preferable, as variations in readings on charge mean little except to one experienced in the handling of storage batteries.

Joint Hydrometer and Voltmeter Tests. In making any of the joint tests described below, it is important to take into consideration the following four points:

(1) The effect of temperature on both voltage and hydrometer readings.

(2) Voltage readings should only be taken with the battery discharging, the load being proportioned to the size of the battery, as voltage readings on an idle battery in good condition indicate little or nothing.

(3) In the case of a starter battery, never attempt to use the starting motor to supply a discharge load for the battery, because the discharge rate of the battery while the starter is being used is so heavy that even in a fully charged battery in good condition it will cause the voltage to drop rapidly.

(4) The voltage of the charging current will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, so that readings taken under such conditions are not a good indication of the battery's condition.

In any battery which is in good condition, the voltage of each cell at a normally low discharge rate (20 to 30 amperes for a vehicle battery or 5 to 10 amperes for a starting-system battery) will remain between 2.1 and 1.9 volts per cell until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or that it is in bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on a few minutes. The joint hydrometer and voltmeter tests given below will be found to cover the majority of cases met with in actual practice.

(1) A voltage of 2 to 2.2 per cell with a hydrometer reading of 1.275 to 1.300 indicates that the battery is fully charged and in good condition.

(2) A voltage reading of less than 1.9 per cell with a hydrometer reading of 1.200 or less indicates that the battery is almost completely discharged.

(3) A voltage of 1.9 or less per cell with a hydrometer reading or 1.220 or more indicates that excess acid has been added. Under these conditions, lights will burn dimly, although the hydrometer reading alone indicates the battery to be more than half charged.

(4) Regardless of voltage—high, low or normal—any hydrometer reading of over 1.300 indicates that an excessive amount of acid has been added.

(5) Where a low voltage reading is found, as mentioned in cases 2 and 3, to determine whether the battery is in bad order or

merely discharged, stop the discharge by switching off the load, and put the battery on charge (crank the engine by hand in the case of a starter battery) and note whether the voltage of each cell promptly rises to 2 volts or more. If not, the cell is probably short-circuited or otherwise in bad condition.*

Cleaning Repair Parts. The advent of electric starting and lighting systems has added appreciably to the amount of attention required by machines in the garage, particularly as this essential is a part of the car about which its owner generally knows little. In fact, it is not overstating it to say that fully 25 per cent of all the repair work now carried on in the garage has for its object the keeping of the electrical equipment of the car in good operating condition. Where many cars are cared for and repairs to their electric systems are made as far as possible right in the garage, it will be found advisable to install a method for cleaning parts. Owing to the accumulations of dirt and grease that parts carry after having been in service for a year or more, cleaning them thoroughly before making any repairs makes it possible to detect defects which might otherwise pass unnoticed. The following instructions are reprinted through the courtesy of the makers of the Delco apparatus, and they strongly recommend that the solutions mentioned be used in the exact manner

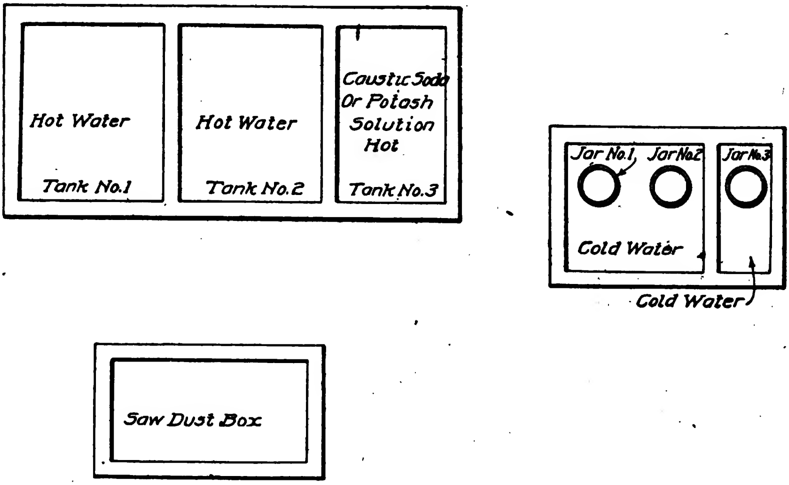

Fig. 408. Layout for Battery Cleaning Outfit

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* From instructions issued by the Prest-O-Lite Company, Indianapolis, Indiana.

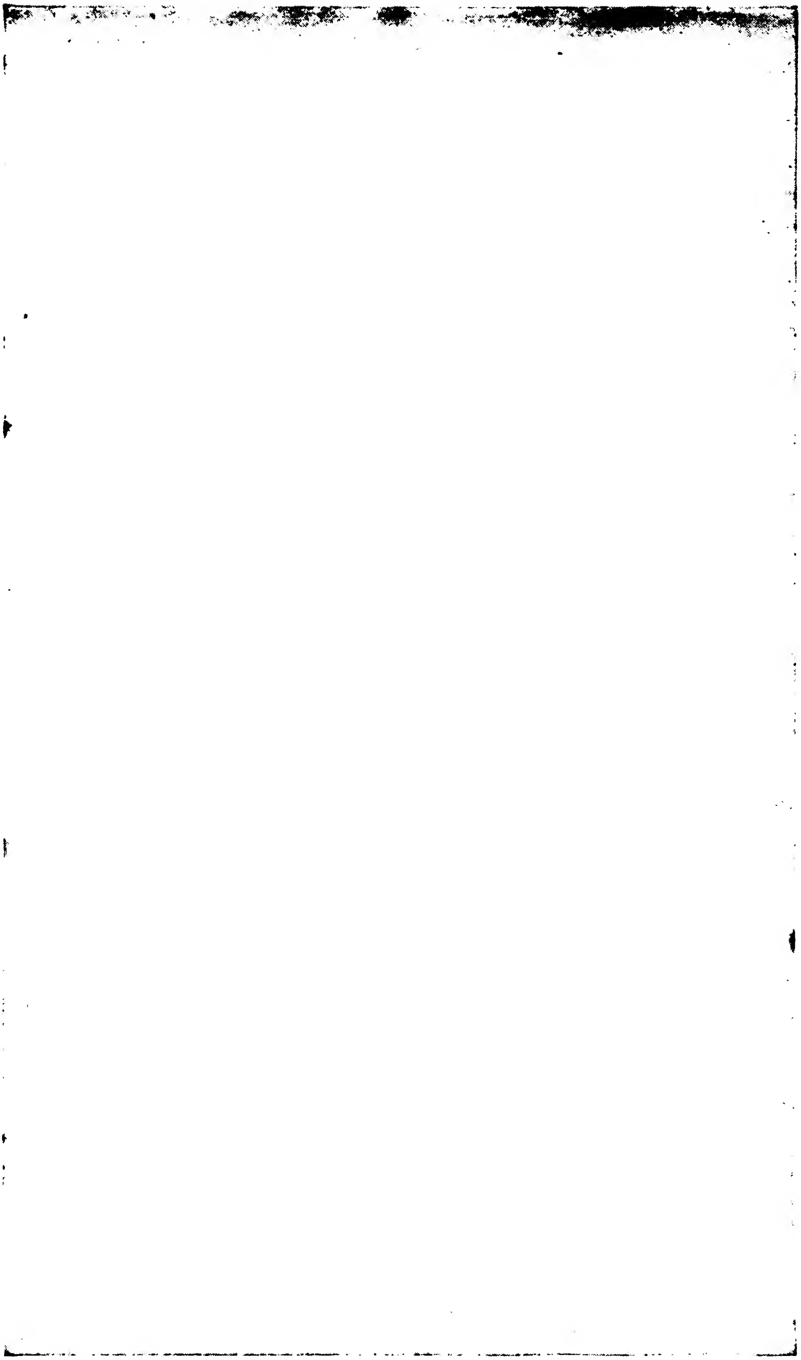
directed, as they are the result of several years' experience in this work, and considerable care has been used in checking them. The sizes of the tanks given are merely indicative of what a very large repair shop would require and are comparative only. They will naturally vary with the amount of work to be done.

Cleaning Outfit. The cleaning outfit should consist of three sheet-steel tanks, Fig. 408, of suitable size (35 gallons for a large shop) mounted so that their contents may be kept heated to the desired temperature, three stone jars of approximately 15 gallons capacity, and a sawdust box. Two of the steel tanks should be equipped with overflow pipes so that they can be kept about two-thirds full at all times. These are tanks No. 1 and No. 2. They are used for clear hot water for rinsing parts after they have been cleaned. The third tank does not require a drain nor an overflow pipe and is used for the potash or caustic soda solution. This can be used for a long time without changing by simply adding a small amount of soda as the solution weakens. All three tanks are maintained at a temperature of 180° to 212° F., or approximately the boiling point.

The three jars mentioned are used for the acid solutions and are referred to as jars No. 1, No. 2, and No. 3. A wood tank large enough to hold the three jars and divided into two compartments, as shown in Fig. 408, should be provided. This is important, as the parts cannot be rinsed in the same cold water after being immersed in the different acid solutions. The solutions recommended are in tanks 1 and 2, clear hot water; tank 3, a solution consisting of one pound of caustic soda per gallon of water. Jar No. 1 is filled with a solution consisting of four gallons of nitric acid, one gallon of water, and six gallons of sulphuric acid. The water is placed in the jar first, the nitric acid is added slowly, and the sulphuric acid is poured in last. This order must be strictly followed, as it is dangerous to mix a solution of these acids in any other manner. In jar No. 2, the solution is one gallon of hydrochloric acid to three gallons of water, while jar No. 3 contains a solution of one-half pound of cyanide to a gallon of water. Tank No. 2 should be used only for parts which have been in the potash solution and for no other purpose. Tank No. 1 is for general rinsing purposes.

Method of Cleaning Parts. Various metals are cleaned as follows: Steel is boiled in the potash solution until the dirt is removed, which should require only a few minutes. The steel part is then rinsed in tank No. 2 and dried in sawdust. Cast iron parts are boiled in the potash solution to remove dirt, rinsed in tank No. 2, dipped in the acid solution in jar No. 1, rinsed thoroughly in cold clear water, dipped in the cyanide solution, rinsed again in cold clear water, then rinsed in tank No. 1 and dried in sawdust. Copper can be cleaned in the same manner. Polished aluminum should first be thoroughly washed in gasoline, rinsed in tank No. 1, dipped in the acid solution in jar No. 1, rinsed thoroughly in cold clear water, rinsed in tank No. 1, and dried in sawdust. Plain aluminum, unpolished, should be dipped in the potash solution, rinsed in tank No. 2, dipped for a few seconds in the acid solution, rinsed in tank No. 2, dipped for a few seconds in the acid solution in Jar No. 1, rinsed in cold water, then rinsed in tank No. 1, and dried in sawdust.

It will be noticed that when aluminum is put into the potash solution the metal is attacked and eaten away rapidly, so that polished parts of this metal should not be put into this solution, and any aluminum parts should not be left in for a moment longer than necessary. Where the parts are covered with caked deposits of hard grease, they should first be washed in gasoline. Aluminum parts should never be put into the potash solution unless they can be put through the acid immediately after, as the acid dip neutralizes the effect of the potash solution. Parts should only be held in the acid for a few seconds. Paint should first be removed with a good paint or varnish remover unless it is present in very small quantity, and unless the aluminum parts are to go through the potash solution. Enameled work should be washed with soap and water, dried thoroughly, and then polished with a cloth dampened with a good oil, such as Three-in-One. These cleaning methods apply only to solid parts and should never be employed on any plated pieces, as the caustic and acid would immediately strip off the plating. Such parts can be cleaned only in gasoline. It will be apparent, however, that cleaning in this manner will be found advantageous for many parts of the car that have to be repaired other than those of the electric equipment, and, in view of the increasing cost of gasoline, will be found much more economical as well as much more thorough.



REMY IGNITION DISTRIBUTOR, MODEL 355-B
Courtesy of Remy Electric Company, Anderson, Indiana

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART VIII

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

SUMMARY OF INSTRUCTIONS ON ELECTRIC STARTING AND LIGHTING

It will be apparent from the foregoing description of the various systems that while the majority differ more or less in detail all are based on a comparatively small number of well-defined principles, and that once these are mastered their application in any system under consideration will be clear. To avoid unnecessary duplication in the instructions covering points that are common to all, general instructions have been given only in connection with one or two systems, and it will be understood that descriptions of the methods of locating short-circuits or grounds, of caring for brushes and commutator, and of testing with a portable lamp or with the volt-ammeter are equally applicable to all. The instructions given with other systems accordingly are limited to special references to the details of installation that will make it easier to locate faults in that particular system.

In order to bring the two together in such form that the particular information desired may be found instantly, a summary of all the instructions given in the preceding sections is outlined here in questions and answers.

GENERATORS

Types and Requirements

Q. How many types of generators are used in starting and lighting service on the automobile?

A. Practically all are of one type, i.e., compound-wound, but this is subdivided into other types, such as differential compound-wound, cumulative compound-wound, and the like, that is, all lighting generators have a shunt and a series winding on their fields, but the relation of these windings to one another differs, depending upon the characteristics of the remainder of the system.

Q. What is a differential compound-wound generator?

A. One in which the series winding is reversed, i.e., wound in a direction opposite to that of the shunt winding so that its exciting effect on the field magnets opposes that of the shunt winding. The series winding is then termed a bucking coil because it bucks, or opposes, the exciting effect of the shunt winding on the field magnets as the speed increases. The series winding in this case is used simply for regulating the generator output.

Q. What is a cumulative compound-wound generator?

A. One in which the exciting effect of the series coil is added to that of the shunt coil, the series coil in this case having no connection with the regulation of the generator output.

Q. As one of the chief requirements of an efficiently operating system is the control of the generator output under widely varying speeds, how is a generator of the cumulative compound-wound type employed on the automobile?

A. The series winding is in practically an independent circuit in connection with the lamps of the car so that its exciting effect is not added to the field magnets except when the lights are switched on. This automatically increases the generator output in accordance with the number of lights turned on so that the lights have no effect on the battery charging rate, which remains the same whether the lights are on or off. An external regulator is employed to control the battery-charging rate.

Q. How does the generator differ from the motor?

A. Its essentials are all the same, i.e., it has a wound armature revolving in a magnetic field, commutator, brushes, etc., exactly the same as the generator.

Q. This being the case, why are the two not interchangeable?

A. To a certain extent they are, that is, when a current is sent through the generator from an outside source, it becomes motorized and will run as a motor. But the two are far from being interchangeable on the automobile, owing to the widely differing requirements for which they are designed. The generator is wound to produce a current seldom exceeding a value of 20 amperes while being driven over a wide range of speeds, and it is in constant operation. The starting motor, on the other hand, is designed to utilize an extremely heavy current, ranging up to 300 amperes or more at the moment of starting and is only used for very short periods.

Q. How are these widely varying requirements reconciled in the single-unit type, in which both the generator and the motor are combined in one machine?

A. The machine is practically two units in one, i.e., there are two totally different windings on the same magnet cores, a fine winding with shunt fields for the generator, and a very heavy simple series winding for the motor end. In some cases, as in the Delco, the different windings on the armature are brought out to independent commutators. While combined on one set of magnet cores, there is no connection whatever between the two windings in such a machine, so that when operating as a generator the motor windings are dead, and the reverse is true when being used as a starting motor.

Q. What are the characteristics of the single-unit type of machine which is simply placed in circuit with the battery by a hand-operated switch when starting and left in that relation as long as the engine is running?

A. This is a variable-potential type in which the relation that it bears to the battery and to the engine is entirely dependent upon the speed of the engine, that is, the speed at which the machine is driven. When the switch is closed, current from the battery operates the machine as a starting motor; as soon as the engine starts and attains a certain speed, the voltage of the machine overcomes that of the battery, the direction of current flow is reversed, and the battery begins to charge. Whenever the driving speed falls below a certain point, there is another reversal, and the generator once more becomes a motor until the engine speed increases.

Loss of Capacity

Q. What are the chief causes for the falling off in output of the generator?

A. In about the order of the frequency of their occurrence, these are as follows: dirty or worn commutator; worn brushes making poor contact; dirty or loose connections causing extra resistance at generator, regulator, cut-out, ground, or battery terminals; failure of cut-out to operate at proper voltage; worn or pitted contacts in regulator or cut-out; loose connections at brush holders; short-circuited coils in the armature; some of the armature-coil connections broken away from the commutator; short-circuited bars in the commutator.

Q. How can the generator output be tested?

A. The simplest method is to switch on all the lamps with the engine idle. Start the engine and speed up to equivalent of 15 miles per hour. The lights should brighten very perceptibly, the test being made indoors in the daytime with the lights directed against a dark wall, or preferably at night. A more accurate test can be made with the portable volt-ammeter, using the 30-ampere shunt. Most generators have an average current output of 10 to 12 amperes, but the normal output as given by the maker should be checked before making the test. Generators having a constant-voltage control will show a greatly increased output if the battery charge is low, running up to 20 amperes or over. On such machines, the condition of the battery should be checked either with the hydrometer or with the voltmeter before making the test. The charging current should be 10 to 12 amperes with a fully charged battery, and more in proportion when only partly charged.

Q. What other simple method is there of determining quickly whether the generator is producing its normal output or not?

A. On generators having an accessibly located field fuse (there are several makes) lift this fuse out and, with the engine running at a speed equivalent to 10 miles per hour or more, touch the fuse terminals lightly to the clips. If the machine is generating properly, there will be a bright hot spark. Should no spark appear, replace the fuse and bridge the terminals with a pair of pliers by touching the jaws to the fuse clips; if a spark appears, the fuse has blown. Before replacing with a new fuse, find the short-circuit or other cause.

Q. Granting that the fuse has not blown, that the cut-out, regulator, and wiring are all in good condition, and still the generator does not produce any current, what is likely to be the cause?

A. One of the brushes may not be touching the commutator, a brush connection may have broken, or carbon dust may have short-circuited the armature or field windings. Test for short-circuits.

Q. If the machine is generating current, and the auxiliary devices and wiring are in good condition, but the battery does not charge, what is the cause?

A. Short-circuit in the battery due to active material having been forced out of the plates, or accumulation of sediment touching plates at their lower ends. (See Battery Instructions.)

Q. Is the regulator ever responsible for a falling off in the current or for generation of excessive current?

A. Yes. Any irregularity in the operation of the regulator will affect the output of the generator.

Q. How can this be overcome?

A. This will depend upon the type of regulation employed (see Regulation). Where the method of regulation is inherent, i.e., forming part of the construction of the generator itself, such as the third-brush method, or a bucking coil, it may be remedied by cleaning and seating the brush properly or by testing the bucking-coil winding to see if its connections are tight and clean, or if it is short-circuited (see Windings). If cleaning and sanding-in the brush do not cause the generator to produce its normal output, the brush itself may be adjusted by shifting its location. Moving it backward or against the direction of rotation of the commutator will reduce the output; moving it forward or in the direction of rotation will increase the output. This refers specifically to the Delco regulation already described. To adjust properly, the portable ammeter should be put in circuit, and the effect on the reading noted as the brush is moved, clamping it back in place when the proper point is found. The brush should then be sanded-in to the commutator, as it will not have a good bearing if its original location has been disturbed.

Methods of Regulation

Q. Why is it necessary to control the output of the generator?

A. As explained in the section on electric generators, the amount of current produced depends upon the excitation of the fields, and the faster the armature revolves before the pole faces of the field magnets, the greater the amount of current that is sent through the windings of the magnets. As the speed of the automobile engine varies between such extremely wide limits, it will readily be seen that it may rise to a point where this increase in the field excitation will cause so much current to be generated that the armature windings will be literally burned up. This happened very frequently in the early attempts to produce a lighting dynamo for automobile service. Regardless of how fast the generator may be driven, it is essential that its current output does not exceed a certain safe limit.

Q. What is the usual safe limit in the majority of generators?

A. Most automobile lighting-system generators are designed to produce 10 to 15 amperes at a normal speed, i.e., sufficient to light all the lamps and still provide a slight excess for charging the battery. No matter how fast its armature revolves, it must not exceed this by more than ten to twenty-five per cent, as a rule, this being well within its factor of safety. In some instances, where a voltage system of regulation is employed, the output of the generator depends upon the condition of charge of the battery. If the battery is practically discharged, the generator will charge the battery at a rate of twenty amperes or over. As the charge proceeds, the battery voltage increases and the resistance is increased correspondingly, thus cutting down the amount of current that the generator can force into the battery.

Q. How is the current generated kept from exceeding this safe limit?

A. Mechanical methods were employed at first, a centrifugal governor being used to operate a slipping clutch. The generator was driven through this clutch, and the speed at which the armature revolved depended upon the engagement of the clutch; at low speeds both shafts would turn at the same rate. As the driving-shaft speed increased, the governor decreased the pressure on the clutch spring, and the clutch faces slipped on one another, so that the driven shaft turned proportionately slower than the driving shaft. The earliest types of governors, employed about 1903 to 1905, were not successful, but about 1908 a type was developed that worked effectively on thousands of cars. It has since been superseded by electrical methods of regulation, and practically all of those now in use are electrically operated.

Q. How many electrical methods of regulating the amount of current generated are in general use?

A. So far as their principle goes, practically all are the same.

They depend upon weakening the excitation of the fields of the generator to cut down the output. It is in the methods of accomplishing this that they differ. In the latter respect they may be divided into two general classes: those that are inherent in the design of the machine, i.e., the regulating device is actually a part of the machine itself; and those in which an external regulator is employed. Those most commonly employed are, in the first class, the bucking-coil winding and the third-brush method; in the second, an external regulator is usually combined with the battery cut-out and designed to keep either the voltage or the current at a uniform value, usually the voltage.

Q. What is a bucking-coil winding, and why is it so called?

A. We have seen that in a series-wound machine all of the current generated in the armature passes through the field windings and energizes the field magnets; in the shunt-wound machine the wires carry only a part of the current which is proportional to the resistance that the shunt winding of the fields bears to the resistance of the outside circuit. As this outside resistance (the load) increases, more current will be diverted through the path of lesser resistance, or the shunt-wound field, and the output of the machine will increase accordingly. In the compound-wound machine, the relation of the series to the shunt winding is such that it is called upon chiefly to help carry any extra load. In other words, as the demands upon the machine increase, the series winding adds its energizing effect to that of the shunt coil. A generator with a bucking-coil winding is a compound-wound machine, but the series winding is in *the opposite direction* from that of the shunt winding. Consequently, instead of adding to the field excitation caused by the latter, it *opposes or bucks* it, and the more current there is produced in the shunt field by the rise in speed, the more the series winding, or bucking coil, tends to neutralize this excess, thus keeping the amount of magnetic effect produced in the field poles practically uniform, regardless of the speed.

Q. What is the third-brush method of regulation?

A. In a conventional shunt-wound generator, the field windings are directly in shunt with the armature through the brushes; hence, a certain proportion of all the current induced in the armature windings will find its way through the field magnet windings, in proportion to their relative resistance to the outside circuit at the time. Where a third brush is employed, the main brushes are not in shunt with the fields, and they are not depended upon to supply the exciting current for the latter. The third brush instead is used for this purpose. As is well known, the output of a generator depends very largely upon the position of its brushes. In the immediate vicinity of the proper location for a brush, there is a short zone of maximum intensity. As we get away from this toward the next brush, it decreases until at a point midway between the two there is a neutral zone. The third brush is accordingly placed between the two main brushes, and its distance from the nearest main brush determines the amount of current that it diverts from the armature to the field windings. See illustration of Delco generator in section on Methods of Regulation. This method has the advantage of supplying a strong shunt field at low speeds. As the speed increases, the voltage applied to the shunt field decreases, even though that between the two main brushes may have increased.

Regulators

Q. What is a regulator, and what is its purpose?

A. It is an instrument somewhat similar to a battery cut-out, and its purpose is to regulate the output of the generator in order that the latter may not exceed safe limits at high speeds. The regulator is usually combined with the cut-out.

Q. How does the constant-voltage type of regulator operate?

A. The instrument consists of a magnet winding and a pivoted armature, normally held open by a spring and a resistance unit. The winding of the magnet has sufficient resistance to prevent the core becoming energized to a degree where it will attract the armature, unless the voltage exceeds the safe limit determined for the circuit. The voltage increases with the speed of the generator, so that when the latter is driven too fast the attraction of the magnet core for the armature becomes sufficient to overcome the pull of the spring which normally holds the contacts apart. (See description of Bijur voltage regulator.) When the contacts come together, the field circuit of the generator is shunted through the resistance unit; this cuts down the amount of current energizing the fields, the voltage falls off, and the contacts again separate. Unless the speed of the generator is decreased, this action is rapidly repeated, so that the regulator arma-

PLATE 145—PAIGE-DETROIT WIRING DIAGRAM OF MODEL 6-40, REMY SYSTEM

PLATE 146—PAIGE WIRING DIAGRAM OF 1920 MODELS 6-42, 6-55, GRAY & DAVIS STARTING AND LIGHTING, ATWATER-KENT IGNITION SYSTEMS

PLATE 147—PAN WIRING DIAGRAM OF MODEL 250, REMY SYSTEM

PLATE 145—PATERSON WIRING DIAGRAM OF 1914 MODELS 32, 33, DELCO SYSTEM

PLATE 150—PATERSON WIRING DIAGRAM OF 1916 MODEL 6-42, DELCO SYSTEM

PLATE 151—PATERSON WIRING DIAGRAM OF 1917 MODELS 6-45 AND 6-45R, DELCO SYSTEM

PLATE 152—PATERSON WIRING DIAGRAM OF 1920 MODEL 6-47 (USING 7-R CONTINENTAL ENGINE), DELCO SYSTEM

PLATE 153—PATERSON WIRING DIAGRAM OF 1920 MODELS 6-46, 6-46R (USING 7-W CONTINENTAL ENGINE), DELCO SYSTEM

PLATE 154—PEERLESS WIRING DIAGRAM OF 1917 SERIES 2, 3, AUTO-LITE SYSTEM

PLATE 155—PIERCE-ARROW WIRING DIAGRAM OF 1919-20 MODELS 38-48, DELCO LIGHTING AND IGNITION SYSTEMS

PLATE 156—PREMIER WIRING DIAGRAM OF 1914 MODEL A, REMY SYSTEM

PLATE 157—PREMIER WIRING DIAGRAM OF 1915 MODEL 6-50, REMY SYSTEM

PLATE 159—PREMIER WIRING DIAGRAM OF 1919 MODELS 6-B, 6-C, DELCO SYSTEM

PLATE 160—PREMIER WIRING DIAGRAM OF 1920 MODEL 6-D, DELCO SYSTEM

ture vibrates at a high speed as long as the voltage is sufficiently high to energize the magnet.

Q. What is the principle on which this type of regulator operates?

A. The principle that in a circuit having considerable self-induction the amount of current which may be sent through the circuit will decrease if the current be pulsating instead of steady. Every time the contacts of the regulator open, a pulsation, or surge, of current is sent through the field windings of the generator; when they close because of the higher voltage, the current is shunted through the resistance unit, thus cutting it down. The decrease in the amount of current is in proportion to the number of pulsations per minute, i.e., the rapidity with which the vibrating contact operates. The circuit having considerable self-induction is that of the field winding of the generator, owing to its heavy iron core. (See Induction.)

Q. What is the constant-current type of regulator, and how does it differ from the constant-voltage, or potential, type?

A. It consists of an electromagnet and a spring-controlled pivoted armature, so that it is of practically the same construction as the constant-potential type, but it is connected in circuit with the armature of the generator and it is wound to operate under the influence of the current rather than the voltage. Consequently, the pivoted armature is attracted, opening the circuit when the current exceeds a certain predetermined value, usually 10 amperes. In operation, the armature vibrates the same as in the voltage regulator, but the condition of the charge of the battery has no effect on it, so that when set to limit the current to 10 amperes, it will always charge the battery at approximately that rate regardless of the condition of the battery. The only practical difference is that it is wound to actuate under the influence of changes in the current flow and is connected in the armature circuit, whereas the constant-potential regulator is influenced by variations in the voltage and is connected in the field circuit of the generator. The latter has the advantage of charging the battery at a higher rate when the charge is most needed.

Q. What other forms of regulators are employed on lighting generators?

A. The foregoing comprise practically all of the principles employed, but the regulators differ more or less in design and operation. For example, in the Bosch-Rushmore generator, a bucking coil is employed in connection with what is termed a ballast resistor, or resistance unit. This is of iron wire, and it is based on the fact that resistance increases very rapidly with the temperature. The size of the wire is such that it allows 10 amperes to flow without undue heating, so that its resistance is practically unchanged; above this point it heats rapidly and increases in resistance so greatly that all excess current is shunted through the bucking coil. In the Splitdorf generator, the regulator is built in, projections of the pole pieces of the field being utilized in connection with special windings, instead of an independent electromagnet as in the Ward-Leonard and the Bijur. In the U.S.L. generator of the inherently regulated type, regulation is accomplished by the combination of a Gramme ring armature, a special arrangement of connections and of the field windings, and the use of only a part of the fields and armature for generating current. The regulation obtained is based on armature reaction and is similar in effect to the third-brush method. The U.S.L. external type of regulator cuts into the generator field circuit a variable resistance consisting of an adjustable carbon pile. In the Adlake regulator, which is of the constant-potential type, a solenoid operates a switch over the contacts of a variable resistance. The plunger of the solenoid is counterbalanced by a weight, which must be raised to operate the switch. It is adjustable by increasing the weight of this counterbalance.

Q. What attention does the regulation of the generator require?

A. This will depend upon the method employed in each case. Where an external regulator is employed, whether of the constant-potential or the constant-current type, the attention required is practically the same as in the case of the battery cut-out. See that the points are not sticking, and when badly burned or pitted, smooth and true up, taking off as little of the contact point as possible to effect this. When the points have become so badly pitted that this cannot be done, new parts will be necessary.

With the third-brush method, the attention required by this brush is the same as that which must be given the other brushes, i.e., sanding-in at intervals and replacement when worn too short to permit the spring to hold the brush firmly against the commutator.

Where the generator fails to produce sufficient current to keep the battery charged, all other parts of the system being in good condition and the car driven long enough in daylight to charge the battery under normal conditions, the position of the third brush may be shifted to increase the output. Care must be taken not to let it come in contact with the main brush. (See Delco instructions.) In the case of a bucking-coil winding, no attention is necessary, as this is an integral part of the machine itself. As the Splitdorf regulator has moving contact points, the attention necessary is the same as that required for an external regulator of this type. Special regulators, such as the U.S.L. external type, require attention covered by the maker's instructions. (See U.S.L. system.)

Q. When the generator fails to keep the battery charged properly, a normal amount of daylight driving being given the car, is the fault most likely to be found in the regulator?

A. No. It is much more likely to be caused by a dirty commutator, worn brushes, loose connections, or some similar cause which inserts extra resistance in the charging circuit. The movement of the regulator armature is very slight, and the current handled by the contact points is small, so that it will seldom be the cause of the trouble. Other causes, such as those above enumerated, should always be sought first. (See instructions under Generator.)

Windings

Q. Are faults in the generator windings frequent?

A. They constitute one of the least frequent sources of trouble with the machine.

Q. What is likely to cause them?

A. Dousing the machine with water is likely to be one of the most frequent causes of short-circuits or grounds in the generator windings. All electrical machinery is intended to be kept dry. Except where provided with a field fuse, running the generator when disconnected from the battery or with the battery removed from the car is another cause. Excessive speed, in some instances, may generate sufficient centrifugal force to lift the armature coils out of their slots so that the insulation becomes abraded by rubbing against the pole pieces, but this is very unusual. In rare instances, a hard kink left in the wire when winding may crystallize the metal and make it break at that point, due to the vibration. Unless cleaned out at intervals, fine carbon dust from the wear of the brushes may accumulate in the interstices of the windings, and, when aggravated by moisture, this is apt to cause short-circuits.

Q. What are the usual indications of such faults?

A. With a short-circuited generator coil (armature), all other parts of the apparatus and circuits being in good condition, the charging rate will be lower than normal. The ammeter needle will vibrate violently when the engine is running at low speeds, and two or more adjacent commutator bars will burn and blacken. With an open armature coil (broken wire), the indications will be practically the same, and there will be severe sparking at the brushes, causing serious burning of the commutator bar corresponding to the open coil. A grounded armature coil will give the same general indications, and if the machine is a single-unit type, the cranking ability of the starting motor will be seriously impaired. The ammeter, however, will not vibrate as in the former cases. There will be practically no charge from the generator, and the battery will be discharged very rapidly by the starting motor.

In a single-unit machine, when the windings of the generator and the starting motor become interconnected, the indications will be practically the same as those of a grounded armature coil. If the motor windings of a single-unit machine become grounded, there will be an excessive discharge from the battery, while the motor will develop but little power.

Q. How may such faults be located?

A. With the aid of the testing-lamp outfit. Remove the brushes (when replacing them later, be sure to put each brush back in the holder from which it was taken), or the brushes may be insulated from the commutator by placing paper under them. For a grounded coil, place one test point on the commutator and the other on the frame; if grounded, the lamp will light. For interconnected motor and generator windings in a single-unit machine having two commutators, insulate the brushes as mentioned and place the test points one on each commutator. The light will burn if the two windings are connected. For a grounded-motor winding, test from the motor commutator to the frame; the light should not burn if the insulation is all right. For a break or open circuit in the field winding, touch the terminals of the latter with the test points, the commutator being insulated or the armature removed. The lamp should light. For a blown field fuse on machines so equipped, place the points on the clips; if the fuse is intact, the lamp will light.

Q. Are these tests conclusive?

A. No. They will indicate any of the faults mentioned, but they will not reveal an internal short-circuit in the windings, which cuts some of the armature or field turns out of action but does not break the circuit as a whole. Such a short-circuit reduces the output of the generator and can be determined definitely only by measuring the resistance of the windings. This requires special and expensive testing instruments, such as the Wheatstone bridge, so that where all other tests fail to reveal the cause of a falling off in the output of the generator, it should be sent to the maker for inspection.

Commutator and Brushes

Q. What does a blackened and dirty commutator indicate?

A. Sparking at the brushes or an accumulation of carbon dust due to putting lubricant on the commutator.

Q. What is the cause of sparking at the brushes?

A. Poor brush contact, due to worn brushes; brush-holder springs too loose, so that brushes are not held firmly against the commutator; excessive vibration, which may be due to a bent shaft, an unbalanced gear pinion, or improper mounting; using too much oil, or using grease in the ball bearings, which gets on the commutator and, acting as a solvent for the binder of the carbon, forms a pasty mass which prevents proper brush contact; worn or roughened commutator on which the mica needs undercutting; overload due to failure of regulator or to grounded coils in armature.

Q. What is the remedy for sparking?

A. Clean the commutator with fine sandpaper and sand-in the brushes to a true bearing on the commutator as directed in the Delco instructions. See that the brush springs have sufficient tension to keep the brushes firmly pressed against the commutator when the machine is running. If the mica protrudes above the commutator bars, it must be undercut as directed, and the commutator smoothed down again after the operation to remove any burrs.

Q. Why do some commutators need undercutting and others not?

A. Undercutting is required only on machines equipped with brushes that are softer than the mica. Copper-carbon brushes, as employed on starting motors to reduce the brush resistance, are hard enough to keep the mica worn down with the copper of the commutator itself.

Q. If, after smoothing off and undercutting the mica, the commutator still has an uneven and irregular surface, what is the remedy?

A. The armature should be removed from the machine, and the commutator trued up in the lathe, taking as light a cut as possible consistent with obtaining a true round and smooth surface.

Q. How can excessive commutator wear be prevented?

A. Inspect at regular intervals and on the first sign of sparking smooth up the surface and sand-in the brushes. Keep the commutator clean and do not permit carbon dust or oil to accumulate in the commutator and brush housing. Never replace brushes or brush springs with any but those supplied by the manufacturer for that particular model. The machine will work with any old brush and any old spring that fits, but they will prove detrimental to its operation in a comparatively short time, and its *working* under such conditions will never be satisfactory.

Q. Is discoloration of the commutator ever caused by anything else than sparking?

A. Not actual discoloration which requires cleaning, but the normal operation of the machine produces a purplish blue tinge on the bars, which is sometimes mistaken for discoloration by the inexperienced. This color, in connection with a high polish of the metal, indicates that the commutator is in the best of condition. Once the commutator takes on this high polish, it will operate for long periods without other attention than the removal of dirt by wiping with a clean rag. Sanding to remove this purple tinge is a mistake, as it only destroys the polish without having any beneficial effect.

Q. Is it necessary to lubricate the surface of the commutator?

A. No. The brushes employed are usually of what are termed a self-lubricating type and require no attention in this respect.

Q. Will any harm result from putting light grease, vaseline, or lubricating oil on the surface of the commutator?

A. As all lubricants are insulators to a greater or less extent, the efficiency of the machine will be reduced and, as the voltage is very low, but a slight falling off is necessary to represent a very substantial percentage of the maximum. The use of lubricant of any nature on the commutator also has another harmful effect in that it collects the carbon dust resulting from the wear of the brushes, causing it to lodge against them as well as between the commutator bars.

Q. Why should particular care be taken to remove all carbon dust from the commutator housing of both the generator and the motor (two-unit system) or the single unit where both functions are combined in one machine?

A. Carbon dust is an excellent conductor of electric current and, when spread over the surface of an insulator, it causes the latter to become conducting as well. Consequently, it is likely to short-circuit the commutator bars by lodging between them. It will cause leakage across fiber or other insulating bushing of brush holders when a sufficient deposit accumulates on them. It will penetrate the armature and field windings of the machine and may cause trouble by grounding or short-circuiting them. Especial care should be taken to remove all traces of carbon dust after sanding-in the brushes.

Q. How often should the commutator be inspected?

A. The commutator is the most vulnerable part of any direct-current machine, whether it be a generator or motor, and it should accordingly be inspected at more frequent intervals than any other single part of the entire system. The efficiency of both the generator and the motor depend upon it to a very great extent. Most of the failures of starting and lighting systems that are not due to poor condition of the battery may be traced directly to the commutator.

Q. What is the function of the brushes?

A. To conduct the voltage and current induced in the armature by its revolution through the lines of force created by the magnetic field, to the outer circuit, in the case of an electric generator; and to conduct the operating current to the armature windings from the battery, in the case of the starting motor.

Q. Why must the brushes bear evenly over their entire surface on the commutator?

A. Because their current-carrying capacity depends upon their size, and the latter is based upon the entire surface of the end of the brush making efficient contact. If the brush does not make uniform contact, those parts of it that do not touch the commutator will cause arcing or heavy sparking at the gap thus created, resulting in damage to both the commutator and the brush.

Q. Why are springs of different strengths used on generators and motors of different makes to hold the brushes against the commutator, though the machines are of practically the same capacity, operate at the same voltage, and are in other respects very much alike?

A. The carbon compounds of which the brushes are manufactured differ greatly in their conductivity and resistance offered to the passage of the current, and these differences call for greater or less spring pressure to hold the brush against the commutator surface in order to make efficient contact over the entire surface of the brush. Every maker has his own standard in this particular respect.

Q. Why is it not advisable to use brushes other than those supplied by the manufacturer as replacements on a machine?

A. For the reasons just given above. The manufacturer has adopted certain standards for the operation of his machines, and the brushes supplied have been made particularly to comply with those standards. No other brushes will do so well, and some will result in injury to the machine.

Q. When inspection shows that the brushes have worn down unevenly, what should be done?

A. They should be sanded-in with a strip of fine sandpaper, such as No. 00, preferably already worn if the brushes are very soft. (See instructions for doing this properly in connection with machines of different makes.) No more should be removed than is absolutely necessary to bring the end of the brush to a firm contact all over its bearing surface on the commutator; and the end of the brush, after the completion of the operation, should not show any deep scratches or pit marks. Unless the surface is smooth and true, injurious sparking will result, and the efficiency of the machine will be decreased.

Q. If, with a smooth and true surface, the brush still fails to make good contact, what is the trouble?

A. The brush has probably worn down until it is too short for the spring to exert sufficient force against it to hold it against the commutator properly, or the spring itself may be at fault. Wear of the brush beyond the point where it is any longer of service will most often be the cause.

Q. Where the brushes are true and are making good contact against the commutator, but the machine is inoperative, all other parts of the system being in good condition, what is likely to be the trouble?

A. One of the pigtails, or short flexible connections, of the brushes may have shaken out from under its spring clip. This breaks the circuit, just as a parted wire or a ruptured connection at a terminal in any other part of the system would.

Q. How often is it necessary to replace the brushes?

A. This differs so much with different makes of machines that it cannot be answered definitely, even as an average. On two-unit systems, the generator brushes will naturally require replacements much sooner than those of the starting motor, as the starting motor is only in operation for very short periods, while the generator is working constantly. On single-unit types, this naturally does not apply, as, whether the armature has one or two sets, they are always in use. Ordinarily, brushes should not require replacement under a year, and frequent instances are known of their having lasted for two years or more. It depends upon the care given the commutator and brushes quite as much as upon the mileage covered, as, if allowed to run dirty for any length of time, the brushes will wear away much faster than if kept in good condition. The best rule for the replacement of the brushes on all makes of machines is to renew them as soon as they have worn to a point where the springs no longer hold them firm against the commutator. When they have reached this condition, the vibration and jolting of the car is likely to shake them out of contact, which results in sparking.

Q. What is the "third brush", and what is its function?

A. This is an extra brush used on a generator. Its purpose is to control the amount of current supplied by the armature to the shunt-field winding as the speed increases. In other words, it regulates the output of the machine and prevents it from being burned out when the speed of the engine becomes very high.

Q. Does it differ from the other brushes in construction or in the care required?

A. It is a carbon brush of the same nature as the others used on the same machine, and the care required to keep it in good condition does not differ. However, it is mounted in an independently adjustable holder so that it may be moved backward or forward with relation to the main brushes in order to increase or decrease the output of the generator. (See instructions [Delco] on this point.)

Q. Is it ever necessary to alter the location of the brushes of a machine?

A. Except on generators fitted with the third-brush method of regulation, on which it may be necessary to shift the main brushes slightly to avoid having the third brush come in contact with one of them when moved to change the output, it should never be necessary to shift the location of the brushes. Brush location has an important bearing on the operation of the machine, and, in designing it, the maker has fixed the location of the brushes to conform to its other characteristics. Many machines have no provision for adjusting the brushes in this respect, while some manufacturers caution the user particularly against altering their location.

Q. How much spring pressure is usually employed to hold the brushes of the generator and starting motor against the commutator?

A. This varies with different makes of machines and should be ascertained from the maker's instructions in every case in order to check up properly. In the various models of the Gray & Davis starting motors, this spring pressure ranges from 2¼ to 3½ pounds, which is the minimum necessary. In other words, the brush must be held against the commutator with this amount of pressure in order to operate efficiently. While there will be a loss if the pressure drops below the minimum, there is no advantage in greatly exceeding it, as excess pressure simply causes greater friction loss without any compensating gain in power. Generator-brush pressures are much less than those employed on starting motors, owing to the smaller amount of current handled.

Q. How can the proper spring pressure of the brushes be checked?

A. With the aid of an ordinary spring scale of the direct-pull type, in which the pull on the hook draws the pointer down over the scale. A scale reading to five pounds is adequate for the purpose; one intended for heavy weights is not likely to be so accurate. Attach the hook of the scale to the brush and pull until the brush is just clear of the commutator. The scale will then register the pull in pounds. Where there is nothing on the brush to which to attach the hook, such as a screw, place a thin piece of wood on the brush face before passing the hook of the scale around it, to prevent injuring the contact face of the brush. In this case, the spring pressure as shown on the scale will exceed the necessary minimum, as the spring must be compressed further than it would be when in operation, in order to operate the scale. This should be allowed for when taking the reading.

Q. When is it advisable to check the spring pressure of the brushes?

A. When there is undue sparking at the commutator, while the commutator and brushes are all in proper condition, i. e., clean, and bearing uniformly over their entire surface so that the sparking is not due to any fault in either of these essentials.

Q. When the brushes and commutator are in good condition and the spring-scale test shows that the brushes are being held against the commutator with the necessary amount of pressure, what is likely to be the cause of the sparking?

A. There may be a short-circuited or open coil in the armature.

STARTING MOTOR

Q. In what way does the starting motor of a two-unit system differ from the generator?

A. It is a simple series-wound machine having but one winding of coarse wire on the fields, and all the current from the battery passes through its armature coils and field windings.

Q. Is it subject to electrical faults other than those already referred to in connection with the generator?

A. No. The care and the nature of the tests required to locate faults are the same. The commutator should be kept clean, brushes bearing firmly on commutator, and all connections kept tight. The same instructions for sanding-in brushes and keeping the commutator in good condition apply as in the case of the generator.

Q. When the starting motor fails to operate, what is likely to be the cause?

A. In the majority of instances, a low state of charge or a wholly discharged battery will be responsible. If the battery is all right, a loose connection at the battery, switch, or motor, or a short-circuit in some part of this wiring may be the cause. Should the battery be properly charged, all wiring and connections in good condition, switch contacts clean, etc., the starting gears may be binding, owing to dirt or lack of alignment between the motor shaft and the flywheel of the engine. In this case, the motor will attempt to start when the current is first turned on, but will be held fast. Loosen the holding bolts and line up the motor, cleaning the gear teeth if necessary.

Q What is likely to be the cause of the starting motor running slowly and with very little power?

A. Exhausted battery, poor switch contacts, loose connections, partial ground or short-circuit in wiring causing leakage, improperly meshing gears, dirty commutator, brushes making poor contact owing to weak springs or worn brushes, or a ground in the motor itself. The remedies for all these faults have been given already.

Q. When the battery and all connections and wiring are in good condition, but the motor fails to crank the engine, what is likely to be the cause?

A. The engine may be too stiff. If it has been overhauled just previously, the main bearings may have been set up too tight. Test with the starting crank to see if it can be turned over easily by hand. If unusual effort is required, easing off the bearings should remedy the trouble. Should the engine not turn over as soon as the switch is closed, release immediately, as otherwise the battery will be damaged.

Q. When the engine does not start within a few seconds, why is it better to use the starting motor intermittently than to run it continuously until the engine does fire?

A. The intermittent use of the starting motor, say ten seconds at a time, with a pause of half a minute or a minute between attempts is easier on the battery. If allowed to rest for a short period, the storage battery recuperates very rapidly. Consequently, the operation of the starting motor for two minutes, divided into twelve periods of ten seconds each, will not run the battery down to anything like the extent that its continuous operation for the same length of time would. Moreover, this intermittent method of operation increases the chances of starting under adverse conditions, as, in very cold weather, every time the battery is allowed to rest, it will be able to spin the engine at its normal starting speed, whereas if the starting motor is operated continuously, the battery will become so weak that the engine will be turned over very slowly toward the end of the period in question.

Q. Why is it that a starting motor capable of turning an engine over at a speed anywhere from 75 to 150 r.p.m. will sometimes fail to start the engine, whereas hand cranking subsequently resorted to will succeed?

A. It must be borne in mind that the operation of starting an engine in cold weather involves several factors. (1) The pistons, crankpins and crankshaft (bearings) must be broken away, i.e., forcibly released from the hold that the gummed lubricating oil has on them, before they can be moved. The great difference between the power required to do this in summer and in winter is shown by the greatly increased amount of current used by the starting motor. (2) Gasoline and air must be drawn into the cylinders, to effect which in sufficient quantity to start the engine requires quite a number of revolutions. (3) The gasoline must be vaporized so that it will mix with the air, which involves more turning of the engine to create the necessary heat by compression in the combustion chambers and the friction of the moving parts. In the application of energy in any form, two factors are always involved, i.e., the unit, or quantity of power applied, and the length of time during which it is applied. The starting motor cranks the engine at a comparatively high speed for a brief period. In hand cranking, a smaller unit of power is employed, and the speed of cranking is accordingly less, but its application is continued for a much longer time. The failure of the starting motor is not due to its inferiority to hand cranking, but simply to the fact that the battery has become exhausted. Success in hand cranking where the starting motor has failed is usually due to the fact that the starting motor has done all the preliminary work, failing in the end simply because the storage battery did not have sufficient energy to finish the task. No electrical starting system can ever be any stronger than its storage battery, or source of energy.

Q. Why is it not necessary to protect the starting motor or its circuit by fuses or other protective devices as in the case of the generator?

A. A simple series-wound machine (practically all electric starting motors are of this type) is capable of standing exceedingly heavy overloads for short periods, it being nothing unusual for these small motors to have a factor of safety of five, or even seven, for a limited time, that is, they will take five to seven times the normal amount of current for a brief period without injury. As a matter of fact, the starting motor can utilize all the current the battery is capable of supplying, provided the motor is free to move. If the engine is stuck fast or some part of the starting system has gone wrong so that the electric motor cannot turn over, then there is danger that the motor may be damaged unless the switch is opened at once. This, together with the fact that the maximum load which may be placed on the motor at different times is such a variable quantity, would make it a difficult matter to provide a fuse that would not blow unnecessarily. The only object of the fuse would be to protect the motor windings, and, as the latter can stand all the current the battery can supply, the only source of danger is the possibility of the motor being held fast so that its armature cannot revolve.

WIRING SYSTEMS

Different Plans

Q. What is the difference between the single-wire and the two-wire systems?

A. In the single-wire there is but one connection to the operating circuit by means of a wire or cable, the circuit being completed in every instance by *grounding* the other side of the circuit. For this reason the single-wire is also referred to as a grounded system. In the two-wire system, copper wires or cables are employed to complete the circuits between the generator and battery and between the battery and the starting motor, as well as to the lamps.

Q. What forms the return circuit of a single-wire system?

A. The steel frame of the chassis.

Q. How are the various circuits grounded?

A. In the case of the battery, a special ground connection is usually made by drilling the frame and fastening a clamp to it. The ground cable from the battery is attached to this clamp. The generator and starting motor are grounded internally, i.e., the end of a winding or of a brush lead that would be taken out to form the return side of a two-wire system is connected to the frame of the machine, and the latter completes the connection to the chassis through its holding bolts or other means of attachment. One side of all lamp sockets is usually grounded, so that the bulb itself completes the connection when fastened in place. Sometimes there is a special ground connection from the battery for the return side of the ignition or lighting circuits, and this ground wire is fused.

Q. What are the advantages and disadvantages of the single-wire system?

A. It greatly simplifies the wiring, as but one wire connection is necessary to the apparatus for each circuit, but this advantage renders it more susceptible to derangement through unintentional grounds or short-circuits, since the touching of any metal part of the chassis by a bare wire will cause a short-circuit. This depends to a very great extent, however, on the thoroughness with which the wiring is protected, and, with the armored cables or loom and the junction boxes used on modern installations, it is reduced to a point where both systems are practically on a par in this respect.

Q. What are the advantages and disadvantages of the two-wire system?

A. Each circuit is complete in itself thus rendering it easier to locate faults, while no one connection coming in contact with a metal part of the chassis will cause a ground. The wiring itself, however, is much more complicated, and, with the small space available on the bulb connections, it is more difficult to insulate them properly.

Q. Which system of wiring is favored?

A. The single-wire system will be found on the majority of cars, and the number of makers adopting it is steadily increasing.

Faults in Circuit

Q. What is the difference between a ground and a short-circuit?

A. So far as the effect produced is concerned, they are the same; the difference in the terms referring solely to the method of producing it. For example, if the cable of the starting motor circuit becomes abraded and the bare part touches the chassis or some connecting part of metal, this is a *ground*. But it is also a short-circuit in that the circuit to the battery is completed through a shorter path than that intended. On the other hand, if, in a two-wire system, the two cables of the same circuit become chafed close together and their bared parts touch, this is a short-circuit, but it is not a ground. For all practical purposes, however, the two terms are really interchangeable when applied to faults in the circuit. (See Gray & Davis instructions.)

Q. How may grounds be located in a single-wire system?

A. In any of the fused circuits, the fuse will immediately blow out. Remove the fuse cartridge and shake it; if it rattles, the fuse wire has melted and the fuse is blown. If it does not rattle, short-circuit the fuse clips with the pliers or a piece of metal; a spark will indicate the completion of the circuit and will also indicate that the fuse has blown. If, on bridging the fuse clips, the lamp lights, or other apparatus on the circuit operates, the short-circuit was only temporary. This does not mean, however, that the fault has been remedied; the vibration of the car may have shaken whatever caused it out of contact and further vibration sooner or later will renew the contact with the same result. Inspect the wiring of that particular circuit and note whether the insulation is intact throughout its length. See that no frayed ends are making contact at any of the connections and that the latter are all tight and clean. In case the lamp does not light on bridging the fuse clips, see if the bulb has blown out; if not, use the test lamp by applying one point to the terminal and the other to various points along the wiring.

Q. Does the blowing of a fuse always indicate a fault in the wiring?

A. No. A bulb, in blowing out, frequently will cause a temporary short-circuit that will blow the fuse. To determine this, apply the points of the test-lamp outfit to the bulb contacts; if the test lamp lights, the bulb is short-circuited, and a new fuse and bulb may be inserted without further inspection of the circuit. In case the test lamp does not light on this test, it does not necessarily indicate a fault in the wiring of that circuit, though inspection is recommended before putting in new fuse and bulb. The blowing out of the bulb may cause a short-circuit, which is ruptured by the

PLATE 161—REGAL WIRING DIAGRAM OF 1917 MODEL J, HEINZE-SPRINGFIELD SYSTEM

PLATE 162—REO WIRING DIAGRAM OF MODELS T, N, REMY SYSTEM

PLATE 163—REO WIRING DIAGRAM OF MODEL F 1500-POUND TRUCK, REMY SYSTEM

PLATE 164—ROOT & VANDERVOORT WIRING DIAGRAM OF 1920 MODELS J, R, WAGNER SYSTEM

PLATE 166—SAXON WIRING DIAGRAM OF 1917 MODEL S-4, REMY SYSTEM

PLATE 167—SCRIPPS-BOOTH WIRING DIAGRAM OF 1919 MODELS 6-39, 6-40, REMY SYSTEM

PLATE 168—SCRIPPS-BOOTH WIRING DIAGRAM OF 1920 SERIES B, REMY SYSTEM

PLATE 172—STEPHENS WIRING DIAGRAM OF 1919 MODELS 70, 75, DELCO SYSTEM

PLATE 173—STEVENS-DURYEA WIRING DIAGRAM OF 1915 MODEL D6, DELCO SYSTEM (INTERNAL)

PLATE 174—STEVENS-DURYEA WIRING DIAGRAM OF 1915 MODEL D6, DELCO SYSTEM

PLATE 175—STUDEBAKER WIRING DIAGRAM OF 1914-15 MODELS, GROUNDED BATTERY, REMY IGNITION SYSTEM

PLATE 176—STUDEBAKER WIRING DIAGRAM OF 1914-15 MODELS, INSULATED BATTERY, REMY IGNITION SYSTEM

current burning away the light metal parts that were in contact, such as a small piece of the filament.

Q. Can a short-circuit or ground occur without blowing a fuse?

A. Yes. No fuses are employed on starting-motor circuits owing to the very heavy current used and its great variation depending upon the conditions, such as extreme cold gumming the lubricating oil, tight bearings, binding of the pinion and gear, sprung shaft, starting motor out of alignment, or the like. On other circuits, the amount of current leaking through the fault in the circuit may not be sufficient to blow the fuse, as the capacity of the latter is such that it will carry the maximum current which the apparatus in that circuit will carry without damage—usually 5 or 10 amperes on lighting circuits and 10 amperes on generator-field circuits.

Q. How can such faults be noted?

A. The ammeter, or indicator, will show a discharge reading when the engine is idle and all lamps are switched off.

Q. What is the usual nature of such a fault?

A. The battery cut-out may have failed to open the circuit completely; a frayed end of the stranded wire at one of its connections may be making light contact which will permit a small amount of current to pass; a particle of foreign matter of high resistance may be bridging a gap either at the cut-out or some other part of the circuit; or the ignition switch may have been left on the *battery* contact so that current is flowing through the ignition coil.

Q. How may faults be located in a two-wire system?

A. With the aid of the test lamp, placing the points along the two wires of the circuit at fault from one set of terminal connections to the other, examine all connections in the circuit in question; note whether any wires have frayed ends and, if so, wind them tight together and dip in molten solder. See whether any moving part is in contact with one or both of the wires and whether the insulation of the latter has been worn off. In some two-wire systems there is a ground connection to the battery for the ignition system, in which case tests for grounds in the circuit in question must also be made. Examine the ignition switch for faults; also the switch of the circuit under test. This applies to single-wire as well as to two-wire systems.

Q. What is one of the most frequent causes of short-circuits in a two-wire system?

A. The bulbs and their sockets, owing to the very small amount of space available for the insulation. Dirt or particles of metal may be bridging the small gaps between their insulated contacts. A blown-out bulb also may be responsible, as previously mentioned.

Proper Conduction

Q. Why are different sizes of wire employed in the various circuits?

A. To permit the passage of the maximum current necessary in each circuit consistent with the minimum drop in voltage due to the resistance of the wire and its connections. The voltages employed are so low that any substantial drop due to this cause would seriously impair the efficiency of the system and particularly of the starting motor. For the latter the cables employed are not only large, but they are also made as short and direct as possible to save current as well as expense in the installation.

Q. What is the smallest wire that should be employed in automobile wiring?

A. No. 14 B. & S. gage, and this should be used only for the tail lamp, dash lamp, primary circuit of the ignition, or similar purpose. No. 10 or No. 12 is usually employed for the other lighting circuits.

Q. When, in making alterations on a car, it becomes necessary to extend a circuit, what should be done?

A. The ends of the wires should be scraped clean and bright for at least 2 inches, and a lineman's joint made with the aid of the pliers to insure having it tight. A lineman's joint is made by crossing the bared ends of the wires at their centers at right angles to each other, then wrapping or coiling each extending end tight around the opposite wire; the joint then should be soldered and well taped. A circuit should be extended only by using wire of the same size and character of insulation. None of the foregoing applies to the starting-motor circuit. It is inadvisable to lengthen this circuit if avoidable, but in the rare instances when it would be necessary, new cable of the same size or larger and with the same insulation should be cut to the proper length and the old cable discarded. All terminals should be solidly fastened to the new cable by soldering.

Q. Why is it necessary to use such heavy cable for the connection of the starting motor to the battery?

A. It is essential that the exceedingly heavy starting current be transmitted with the minimum of loss.

Q. What is considered the minimum permissible loss in the starting-system wiring?

A. One maker specifies that the starting cable must be large enough to transmit a maximum current of 400 amperes with not over one-fourth volt total loss.

Q. Why is it important to hold the voltage drop down to a maximum so small as to be negligible in almost any other application?

A. Owing to the heavy current necessary, as a drop of but $\frac{1}{4}$ volt in potential with a current of 400 amperes represents a loss of 100 watts, or close to $\frac{1}{7}$ horsepower. Of course, the current seldom reaches such a high value as this except when a motor is exceptionally stiff, as in severe cold weather or just after its bearings have been set up very tight; moreover, this loss takes place at the instant of starting only, but it is just at this time that the highest efficiency and full battery power is needed to start without spinning the engine too much.

Q. On some of the early systems whose efficiency was not of the best, how can the proper size of cable to use between the starting motor and battery be determined?

A. Test the starting motor with a high-reading ammeter (scale should read to at least 300 amperes) after having made certain by hydrometer and voltage tests that the storage battery is fully charged. (See instructions regarding this.) Carefully note ammeter reading exactly at instant of closing switch, to determine maximum current flow. Measure the length of cable between the battery and the starting motor, i.e., both sides of starting switch. Then maximum starting current times 10.7 times number of feet of cable used, divided by .25 will give the cross-section of the wire in circular mills. For example, assume that the starting motor required a maximum of 300 amperes momentarily to break away the engine, and five feet of cable are employed for the connections. Then

$$\frac{300\times10.7\times5}{25}=128{,}400 \text{ circular mills}$$

By referring to Table I, Part I, which gives the various size wires in circular mills and their equivalent in gage sizes, it will be noted that the closest approach to this is No. 00 cable, which is 133,079 circular mills, so that the largest size cable would have to be used. If the starting cable used on an old system which does not show particularly good efficiency is much smaller than this, it would probably be an advantage to replace it with larger cable, assuming, of course, that every other part of the system is in good condition and working properly.

Q. Why should connections be inspected frequently?

A. The vibration and jolting to which they are subjected in service is so severe that no mechanical joint can be depended upon to remain tight indefinitely.

Q. What harm does a loose or dirty connection occasion?

A. A loose connection causes the formation of an arc between its contacts whenever vibration causes the parts to separate temporarily. This wastes current and burns the metal away, leaving oxidized surfaces which are partially insulating, thus increasing the resistance at the connection. Dirt getting between the surfaces of the connector has the same effect; the resistance is increased and there is a correspondingly increased drop in the voltage of the circuit, which cuts down its efficiency.

Q. Why should all terminals be well taped when the battery, starting motor, generator, or other apparatus is temporarily disconnected for purposes of inspection or test?

A. To prevent accidental short-circuits which would be caused by these terminals coming in contact with any metal part of the chassis on a single-wire system. Such a short-circuit would ruin the battery and burn out any lamps that happened to be included in the circuit. This precaution applies with equal force to the two-wire systems, as in this case the terminals of the different wires might come together, or there might be a ground connection in the system.

PROTECTIVE AND OPERATIVE DEVICES

Q. What are the protective devices usually employed on electric systems?

A. Fuses in the separate lamp circuits, in the ground connection, and in the field circuit of the generator on some machines; battery cut-out for the charging circuit; circuit-breaker which takes the place of the fuses.

Fuses

Q. What is a fuse and what is its function?

A. A fuse consists of a piece of wire of an alloy which melts at a low temperature and which will only carry a certain amount of current without melting, the latter depending upon the diameter of the wire, i.e., cross-section and the nature of the alloy. The fuse is usually in the form of a cartridge, the wire being encased in an insulating tube having brass ends, to which the ends of the wire are soldered. These brass ends are pressed into spring clips to put the fuse in circuit. In some cases open fuse blocks are employed, the wire itself simply being clamped under the screw connectors on the porcelain block. The function of the fuse is to protect the battery and the lamps when, by reason of a ground or short-circuit in the wiring, an excessive amount of current flows.

Q. When a fuse blows out what should be done?

A. Investigate the cause before replacing it with a new one. (See Wiring Systems.)

Q. Is it permissible to bridge the fuse gap with a piece of copper wire when no replacements are at hand?

A. Only in cases of emergency and after the short-circuit which has caused the fuse to blow has been remedied. The finest size of copper wire at hand, such as a single strand from a piece of lamp cord, should be used. If this burns out, there being no ground or short-circuit in the wiring, use two strands. Remove the wire as soon as a new fuse is obtainable.

Q. Why are fuses not employed in the starting-motor circuit?

A. In the starting circuit the current necessary is so heavy and varies so widely with the conditions that it would not be practicable to provide a protecting fuse.

Q. What does the intermittent blowing of the fuse on the same circuit indicate?

A. A short-circuit that is caused by the vibration, or jolting, of the car. The wire, lamp socket, or other part of the circuit that is at fault is shaken loose at times so that the circuit is operative, and a new fuse may be inserted without instantly blowing, as it would do were the short-circuit constant. This is often the case as the car is stopped to inspect the wiring and insert the new fuse, and standing still lets the part drop out of contact; starting up shakes it into contact once more and blows the new fuse. Loose connections, wires with abraded insulation, and bulbs loosely inserted in their sockets are apt to cause trouble of this nature.

Q. Does the blowing out of a fuse necessarily indicate a fault in the wiring or in some other part of the system?

A. No, since a bulb in burning out will frequently cause the fuse to blow out. This is due to the fact that in breaking, the end of the parted filament of the bulb may fall across the other terminal where it comes through the glass, thus causing either a short-circuit or such a reduction in the ordinary resistance as to permit a much heavier rush of current than normal, with the result that the fuse goes. To test, leave burnt-out bulb in place temporarily; short-circuit fuse clips with screw driver or pliers, just touching them momentarily; if no spark results, replace bulb with a new one and test again; if a spark occurs, remove old bulb and test again with no lamp in place; then if no spark occurs in bridging the fuse terminals, the circuit is all right, and the fuse may be replaced.

Q. When all the lighting fuses blow out at once, what does this indicate?

A. A short-circuit across the lighting-switch terminals would cause this. In some switches with exposed rear terminals, it is possible to place a screwdriver or similar piece of metal in such a position that it bridges practically all the switch terminals. If the lighting switches were all closed at the time, this would short-circuit them.

Circuit-Breaker

Q. What is a circuit-breaker, and what is its function?

A. The circuit-breaker is an electromagnet with a pivoted armature and contacts, similar in principle to the battery cut-out. All the current used in the various circuits, except that of the starting motor, passes through it, and its contacts normally remain closed. The winding of the magnet coil is such that the normal current used by the lamps or ignition does not affect it, but the passage of an excessive amount of current will energize the magnet, attract the armature, and break the circuit. The spring holding the armature away from the magnet will again close the circuit, and the circuit-breaker will vibrate until the cause has been removed. This is usually a ground or short-circuit. The function of the circuit-breaker is to protect the battery and lamps in place of the usual fuses.

Q. If the circuit-breaker operates when there are no faults in the wiring, what is likely to be the cause?

A. Its spring may have become weakened so that the vibration of the car causes it to operate on less current. The Delco circuit-breaker is designed to operate on 25 amperes or more, but, once started, a current of 3 to 5 amperes will keep it vibrating. If tests show that no faults in the wiring or connections exist, increase the spring tension with the ammeter in circuit until the reading of the latter indicates that the circuit-breaker is not operating on the current of less value than that intended. See that the contacts are clean and true.

Battery Cut-Out

Q. What is a battery cut-out?

A. It is an automatic double-acting switch which is closed by the voltage of the generator and opened by the current from the battery.

Q. Of what does it consist?

A. It is essentially a double-wound electromagnet with a pivoted armature and a pair of contacts. One winding, known as the *voltage coil,* is of fine wire and is permanently in circuit with the generator. The second winding of coarse wire is termed the *current coil* and is put in circuit by the contacts.

Q. Why is a cut-out necessary?

A. To protect the storage battery. When the generator speed falls below a certain point, it no longer produces sufficient voltage to charge the battery, and the latter then would discharge through the generator windings if not prevented. This discharge would always take place when the generator was idle, except for the cut-out.

Q. How does it operate?

A. When the generator voltage approaches the value necessary for charging, it energizes the magnet through the voltage coil and closes the contacts, cutting in the current coil, which further excites the magnet and holds the contacts firmly together. The closing of these contacts puts the battery in circuit and it begins to charge. As soon as the generator speed falls below the point necessary for charging, the battery voltage overcomes that of the generator and sends a current in the reverse direction through the current coil, causing the contacts to separate and cutting the battery out of the charging circuit.

Q. If the generator is run for any length of time at or near this critical speed, what is to prevent the cut-out from vibrating constantly instead of working positively one way or the other?

A. The resistance of the windings is so proportioned that there is a difference of 1 to 2 volts between the cutting-in and the cutting-out points.

Q. What is the result when the battery cut-out—which is variously termed a cut-out, a circuit-breaker, an automatic switch, and a reverse-current relay or an automatic relay—fails to operate?

A. If it fails to cut in, i.e., the contacts do not come together, the battery does not charge and will quickly show a falling-off in capacity, such as inability to operate the starting motor properly or to light the lamps to full brilliance. If it fails to cut out, the battery charge will be wasted through the generator windings with the same indications of lack of capacity.

Q. What is the most frequent cause of trouble?

A. Automatic cut-outs have been perfected to a point where but little trouble occurs. Freezing or sticking together of the contacts due to excessive current will most often be found to be the cause of the device failing to cut out when the generator is stopped. The points should be cleaned and trued up as described in previous instructions. Loose or dirty connections making poor contact may insert sufficient extra resistance in the circuit to prevent the device from cutting in at the proper point. Excessive vibration, particularly when the cut-out is mounted on the dash, may prevent the contacts from staying together as they should when the engine is running at or above the proper speed. See that the cut-out is solidly mounted. Temporary loss of battery capacity may be due to slow driving over rough roads at about the speed at which the cut-out is designed to put the battery in circuit.

Q. None of the above causes existing, what further tests may be made?

A. The windings may be tested as already described for the generator windings, but trouble from this source is equally rare. If the contacts are clean and true and the connections are tight, look for a loose connection elsewhere, as at the generator or battery or the ground on the frame. A loose connection vibrates when the car is moving, constantly opening and closing the circuit and causing the cut-out to do likewise, so that the battery does not charge. A wire from which the insulation has been abraded will also vibrate, owing to the movement, causing an intermittent short-circuit. With all contacts and connections in good condition, failure to cut out indicates a ground or short-circuit between the battery and cut-out; failure to cut in indicates similar trouble between the generator and the cut-out.

Q. Is a battery cut-out necessary on every electrical system?

A. No. On single-unit systems of the type of the Dyneto, in which the generator becomes *motorized* as soon as its speed and consequently its voltage drops below a certain point, the battery is always in circuit. A plain knife-blade switch, which also controls the ignition, is closed to start and left closed as long as the car is running. But the engine must not be allowed to run at a speed below which it generates sufficient voltage to charge the battery, nor must the switch be left closed when the engine is not running; otherwise, the battery will discharge through the generator windings.

Q. After having trued up points of a battery cut-out, what precautions should be taken in adjusting them?

A. To insure proper operation, they must be set to the distances given in the manufacturer's instructions. This refers not only to the gap between the contact points themselves, but also to the distance that the armature must be set from its backstop when the points are open and to the air gap between the armature and the magnet. These distances are very small in every case, and it is important that they be adjusted accurately. They differ slightly on cut-outs of different makes and also on different models of the same make. For example, in the Gray & Davis cut-out, the distance between the contact points should be .015, the air gap between the armature and its backstop not less than .010, and the armature air gap, or distance between the armature and the magnet face, .030. These dimensions refer to the flexible, or spring-arm type, while in the solid-arm type of the same make, they are .010 for the distance between the contact points and .015 for the armature air gap, it being necessary that the armature should be set parallel with the pole face of the magnet.

Q. How can these small distances be accurately determined with the facilities ordinarily found in a repair shop?

A. The manufacturers usually supply a small adjusting wrench, the different edges of which have been ground to varying thicknesses representing the proper distances for the various gaps. Lacking one of these, small pieces of strip brass or steel may be ground or filed down to the proper size and gauged with a micrometer, which should be part of the equipment of every garage. The strips should be stamped with the dimensions and name of gap for identification.

Q. How often will the point of a battery cut-out need adjustment, or truing up?

A. Service conditions vary so greatly that it is impossible to give any definite average for this, particularly as the instruments themselves also are a variable quantity, but, under ordinarily favorable conditions, they should not require attention more than once a year.

Contact Points

Q. Why is it necessary to make contact points of such an expensive metal as platinum, and why is the latter sometimes alloyed with irridium?

A. There is no other metal which withstands the oxidizing effect of the electric arc and still maintains a clean and bright conducting surface as does platinum. Irridium is added to make the platinum harder, so that it will be more durable. On cheaply made instruments in which no platinum has been used in the contacts, trouble will be experienced constantly with the contacts.

Q. Is there any substitute for platinum or any metal that approaches it in adaptability for contact points?

A. There is no substitute for platinum, and the only metal that approaches it is silver. Where contact points only separate occasionally at intervals, as in the Remy thermoelectric switch, the use of silver contacts is permissible; but in a battery cut-out, or a regulator in which the vibration of the points is more or less constant, nothing will serve so reliably as platinum.

Q. What is the cause of the platinum contacts burning into such irregular ragged forms?

A. When a current of electricity passes through a contact of this nature, the material of the positive electrode (i.e., contact point connected to the positive side of the circuit) is carried over by the current in the shape of metallic vapor, or infinitely fine particles, and deposited on the negative electrode. The positive consequently takes on the form of a sharp point, while the negative has a depression formed in it, usually referred to as a "peak and crater", which the two points resemble in miniature after long use. This peak and crater effect is much more noticeable in an old-style carbon arc lamp after it has been burning only a few hours.

Q. What can be done to prevent this?

A. The passing of the metal from one electrode to the other cannot be prevented, as it is a function of any arc or spark. It can be minimized, however, by keeping the contacts in good condition so that the sparking is reduced to a minimum.

Q. Can the formation of the pack and crater effect, which so greatly reduces the efficiency of the contacts, be avoided?

A: The use of a reversing switch in the circuit, as in the case of the magneto or the battery-type interrupter which changes the direction in which the current flows through the points every time it is turned on, will overcome this. Where there is no reversing switch in the ignition circuit or where one cannot be used, attention to the points at regular intervals will prevent this effect from reaching a stage where most of the point has to be filed away to true it up.

Q. In the use of the file, sandpaper, or emery cloth in this connection, just what is meant by truing the points up?

A. Their surfaces must be made exactly parallel to one another so that when the points come together they touch uniformly over their entire surfaces. In the hands of the unskilled user, there is a tendency to bear down sidewise with the file, thus forming rounded edges on the points. In addition to having the faces of the two points perfectly parallel, the face of each point must be at right angles to its sides. Otherwise, there is bound to be unnecessary sparking between the points, and this causes them to burn away again much sooner. It is scarcely necessary to add that as little as possible of the metal should be removed. As long as there is enough of the platinum left to make true parallel surfaces, the points need not be replaced if the means for adjustment permits utilizing them when worn far down.

Q. What is the cause of the points freezing, or sticking, together?

A. Permitting them to wear down to a point where they are in very poor condition and where the gap between parts of their surfaces causes the formation of a heavy arc, or hot flash of current, which practically welds them together. By giving them the necessary attention at regular intervals, this may be avoided.

Q. How often should the contact points need attention?

A. When new, they should run for a year or more without any attention. After they have been trued up, the succeeding interval will often depend upon the skill and care with which this has been carried out.

Switches

Q. How do switches as employed on the automobile differ in principle and operation?

A. Starting-circuit switches are either of the knife-blade or the flat-contact type, while in the majority of cases the lighting switches are of the push-button type, though knife-blade switches are used for this purpose also. In some instances, one of the brushes of the machine is made to serve as a switch, as in the Delco. Ordinarily, the switch is normally held open by a spring and is closed by foot pressure, the spring returning it to the open position as soon as released. A variation of this is the Westinghouse electromagnetically operated switch in which a solenoid takes the place of foot operation. The circuit of the solenoid is controlled by a spring push button, which is normally held out of contact. Single-unit systems, such as the Dyneto, in which the machine automatically becomes motorized when the speed drops below a certain point, are controlled by a standard single-throw single-pole knife-blade switch which is left closed as long as the machine is running.

Q. What faults may be looked for in switches?

A. Loose connections; weakening of the spring; burning of the contact faces in the knife-blade type, due to arcing caused by releasing too slowly; dirt or other insulating substance accumulating on the contact faces of the flat-contact type; failure to release through binding.

Q. Why is it important to keep the switch contact faces clean and bright?

A. Dirt or burned surfaces increase the resistance and cause a drop in the voltage at the starting motor. The energy represented by an electric current is a measure of the volume or amperes times the voltage or pressure under which it flows, and, as such low voltages are used, only a slight falling off represents a serious percentage of the total potential. With a dirty switch or one that makes poor contact, current that should be utilized in the starting motor is wasted in overcoming the resistance of the switch.

Q. Why is it inadvisable to insert an extra switch in the starting circuit, as is done in some cases by owners to insure against theft?

A. Because of the drop in voltage. The loss in switches as designed for lighting circuits is about 1 per cent, or a little over 1 volt. If the same switch is used on the low voltage of the starter system, the loss is then equivalent to about 10 per cent.

LIGHTING AND INDICATORS

Lamps

Q. How many types of bulbs are there in general use on automobiles?

A. Four: miniature and candelabra screw base, and single- and double-contact bayonet-lock base, both of the latter being of the candelabra size.

Q. Are these types equally favored?

A. No. The screw-base type, particularly in the miniature size, will be found only on old cars, and this type, generally speaking, is practically obsolete on the automobile, as the vibration tends to unscrew the lamp. Of the bayonet-lock type, the single-contact style is steadily gaining favor. Ten million bulbs for automobile lighting were produced in 1915 (S.A.E. report) and of these 67 per cent were of the single-contact type.

Q. In how many different voltages are these bulbs made?

A. Four: a 6—8-volt bulb for a 3-cell or 6-volt system; 12—16-volt bulb for 6-cell or 12-volt systems; and 18—24-volt bulbs for 9-cell systems; 3—4-volt bulbs for tail-light and dash-light use, where these lights are burned in series on a 6-volt system.

Q. Are these the only voltages in which the bulbs are made?

A. No. They are the types that are being standardized to reduce the stock of replacements that it is necessary for a garage to carry. It has been customary for the lamp manufacturer to supply bulbs made exactly for any voltage that the maker of the electric system ordered. Taking into consideration only the standard sizes now listed for use on 3-, 6-, and 9-cell systems, and the different bases regularly used, there are about twenty-four different bulbs that should be stocked by a garage. In addition, about forty other sizes are in general use, and if individual voltages had to be supplied, considering the different standard bases, a stock of over two-hundred different bulb sizes would be required.

Q. Why is the voltage of a bulb expressed as "6—8", "12—16", etc.?

A. Owing to the rise and fall of the battery voltage according to its state of charge, this variation must be provided for, or the lamps would be burned out when the battery was fully charged. Headlight bulbs for 3-cell systems are made for 6½ volts, while the side, rear, and speedometer lights are made for 6¾ volts, owing to the lesser voltage drop in their circuits, but they will all operate satisfactorily on a potential that does not exceed 8 volts or does not drop below 6 volts.

Q. When all the lamps burn dimly, what is the cause?

A. The battery is nearly exhausted, in which case its voltage will be only 5.2 to 5.5 volts for a 3-cell system. The car should be run with as few lights as necessary to permit the generator to charge the battery quickly.

Q. What is the cause of one light failing?

A. Bulb burned out or its fuse blown; examine the fuse before replacing the bulb and if blown, examine the wiring before putting in a new bulb. Poor contact; see that the lamp is put in properly and turned to lock it in place. A double-contact bulb may have been put in single-contact socket, or *vice versa.*

Q. Why will one lamp burn much brighter than the other?

A. A replacement may have been made with a bulb of higher voltage; a 12-volt bulb will give only a dull red glow on a 3-cell system. Where the difference is not so marked as this, but still very perceptible, it may be due to the difference in the age of the lamps. As a bulb grows old in service, its filament resistance increases, so that it does not take so much current and will not burn as brightly as when new.

Q. Will the failure of a bulb cause its fuse to blow though there is no fault in its circuit?

A. This sometimes happens owing to the breaking down of the filament, causing a short-circuit when the lamp fails.

Q. Can the proper voltage bulbs needed for any system always be told simply by taking the total voltage of the battery, i.e., the number of cells times 2?

A. No. Always examine the burned out bulb and replace with one of the same kind. Many 6-cell systems use 6-volt lamps and are known as 12—6-volt systems. The battery is divided into two groups in series parallel for lighting and sometimes for charging, all the cells being in series for starting. Other arbitrary voltages are also adopted; for example, 14-volt bulbs are used on 12-cell systems, the battery being divided in the same manner, so that this would be a 24—12-volt system. The only safe way to order replacements is to give the voltage on the printed label on the old bulb and state the make of the system on which it is to be used.

Q. What type of bulb is used where the current is taken from the magneto, as on the Ford?

A. As supplied by the maker, only the headlights are wired, and they are in series, and in recent models a 9-volt bulb is used, but the above instructions for replacements will apply here also. Ordinarily, double-contact bulbs are required, unless the fixtures are insulated from one another, in which case the single-contact type can be used.

Q. Why is a bulb of a voltage lower than that of the system itself often employed on 6-, 9-, and 12-cell systems?

A. The lower the voltage, the thicker the filament can be made. A short comparatively thick filament concentrates the light and makes the bulb easier to focus; it is also much more durable than the thin filament required for higher voltages.

Q. Under what conditions will the best results be obtained from the head lamps?

A. When the bulbs are in proper focus with the lamp reflectors. The usual focal length for headlight bulbs is $\frac{13}{16}$ inch, and the focal length of the reflector is made greater than this to permit of adjustment. The center of the filament should be back of the focus of the reflector to spread the beam of light. In this position a greater number of the light rays are utilized and redirected by the reflector, producing a higher beam candlepower. If the center of the filament is forward of the focus, the lower part of the reflector will produce the most glare and throw it into the eyes of pedestrians and approaching drivers.

Q. How can the headlights be focused?

A. Place the car in position where light can be directed against a wall about 100 feet distant. Adjust the bulbs backward or forward until the spotlight on the wall is most brilliant and free from black rings and streaks. When this position is found, lock the bulb securely in place. Focus each headlight separately. See that the lamp brackets are set so that the light is being projected directly ahead.

Q. How can metal headlight reflectors be cleaned when discolored?

A. Wash by directing a gentle stream of cold water against the surfaces and allow to dry without touching them. The reflectors should never be rubbed with cloth or paper as it will scratch the highly polished surfaces. If they become very dull, it will be necessary to have them replated.

Q. What is the meaning of the identification marks usually placed on bulbs, in addition to the voltage, such as "G-6"?

A. This refers to the size and shape of the bulb. The diameter of the glass bulb is expressed in eighths of an inch and its shape by a prefixed *G* for round (globular), *T* for tubular, *S* for straight-side, etc. Thus, G-6 is a round bulb $\frac{6}{8}$ inch or $\frac{3}{4}$ inch in diameter.

Instruments

Q. What instruments ordinarily are employed in connection with electric systems on the automobile?

A. Either a double-reading ammeter, a volt-ammeter, or an indicator, the first named being employed generally. The ammeter shows whether the battery is charging or discharging or whether no current is passing; the indicator reads either *Off* or *On*; while the voltammeter gives the voltage, usually upon pressing a button to put it into operation, in addition to the readings already mentioned.

PLATE 177—STUTZ WIRING DIAGRAM OF 1914-15 MODELS, REMY SYSTEM

PLATE 178—STUDEBAKER WIRING DIAGRAM OF 1918 MODELS SH, EH, EG, REMY SYSTEM

PLATE 179—STUDEBAKER WIRING DIAGRAM OF 1920 SERIES 20, WAGNER STARTING AND LIGHTING, REMY IGNITION SYSTEMS

PLATE 160—STUTZ WIRING DIAGRAM OF 1918 SERIES S, REMY STARTING AND LIGHTING, DELCO IGNITION SYSTEMS

PLATE 181—STUTZ WIRING DIAGRAM OF 1918 MODEL 4-S, DELCO IGNITION SYSTEM

PLATE 182—SUN WIRING DIAGRAM OF LIGHT-SIX 1917 MODEL, REMY SYSTEM

PLATE 183—TEMPLAR WIRING DIAGRAM OF 1918-19-20 MODELS A-4-45, REMY SYSTEM

PLATE 182—SUN WIRING DIAGRAM OF LIGHT-SIX 1917 MODEL, REMY SYSTEM

PLATE 183—TEMPLAR WIRING DIAGRAM OF 1918-19-20 MODELS A-4-45, REMY SYSTEM

PLATE 184—VELIE WIRING DIAGRAM OF 1918-19 MODELS 38, 39-7, 39 SPORT, REMY SYSTEM

PLATE 185—VELIE WIRING DIAGRAM OF 1920 MODEL 48, BIJUR STARTING AND LIGHTING, ATWATER-KENT IGNITION SYSTEMS

PLATE 187—WESTCOTT WIRING DIAGRAM OF 1915 MODELS U-6, O-35, DELCO SYSTEM

PLATE 183—WESTCOTT WIRING DIAGRAM OF SERIES 19, DELCO SYSTEM

PLATE 189—WESTCOTT WIRING DIAGRAM OF 1920 MODELS A-38, C-38, DELCO SYSTEM

PLATE 190—WESTCOTT WIRING DIAGRAM OF 1920 MODEL A-38, C-38, DELCO SYSTEM (USING 7R CONTINENTAL ENGINE)

PLATE 191—WESTCOTT WIRING DIAGRAM OF 1920 MODEL C-48, DELCO SYSTEM (USING 9N CONTINENTAL ENGINE)

PLATE 192—WESTCOTT WIRING DIAGRAM OF 1920 TYPE C-48, DELCO SYSTEM (USING 9N CONTINENTAL ENGINE)

Q. On what circuits are the indicating instruments placed?

A. The charging circuit from the generator to the battery, and the lamp and ignition circuits.

Q. Why is an ammeter not used for the starting-motor circuit?

A. The current is so heavy and varies so greatly with the conditions that an ammeter designed to give an accurate reading of it would not be sensitive enough to indicate the smaller amounts of current used by the lamps, or produced by the generator for charging. Furthermore, the starting motor is intended only to be used for very short periods, while the other circuits are in constant use.

Q. Do the small ammeters employed fail very often?

A. Considering the unusually severe treatment to which they are subjected by the vibration and jolting of the car, their failure is comparatively rare, but as the conditions are so severe for a sensitive indicating instrument, too much dependence should not be placed on the ammeter reading when making tests.

Q. What are the usual causes of failure?

A. Failure to indicate—the generator, wiring, and other parts of the circuit being in good operative condition—may be caused by the pointer becoming bent, so as to bind it; the pointer may have been shaken off its base altogether by the jolting, or one of its connections may have sprung loose from the same cause.

Q. How can the ammeter reading be checked?

A. By inserting the portable testing voltammeter in circuit with it, using the 30-ampere shunt and comparing the readings. The dash ammeter must not be expected to give as accurate a reading as the finer portable instrument. Failing the latter, a spare dash ammeter may be employed in the same manner and the spare may be tested beforehand by connecting to a battery of 4 dry cells in series; if brand new, they should give a reading of 18 to 20 amperes. Do not keep the ammeter in circuit any longer than necessary to obtain the reading, as it only runs the cells down needlessly.

Q. Should an ammeter ever be used in testing the storage battery?

A. No. Because it practically would short-circuit the battery, burn out the instrument, and damage the battery itself. Nothing but a voltmeter should be employed for this purpose, as its high resistance coil permits only a small amount of current to pass. An ammeter reading from a storage battery gives no indication whatever of its condition, whereas the voltage affords a close check on the state of charge, varying from 1.75 for a completely discharged cell to 2.55 volts for a fully charged one, the readings always being taken when the battery is either charging or discharging. The voltage on discharge will not be as high as on charge, the conditions otherwise being the same.

Q. Why are indicators employed on some systems instead of ammeters?

A. As the indicator is not designed to give a quantitative reading, it need not be so sensitive as an ammeter and accordingly can be made more durable.

Q. What are the most frequent causes of failure of an indicator?

A. Usually of a mechanical nature caused by the jolting, such as the target being shaken off its bearings, broken wire, etc.

Q. When the engine is running slowly, and the ammeter or the indicator flutters constantly, going from "On" to "Off" at short intervals, in the case of the indicator, or from a small charging current to zero, in the case of the ammeter, what does this signify?

A. That the setting of the battery cut-out is very sensitive and that the engine is then running at or about the speed that the instrument should cut-in. Since the speed of an engine varies considerably when running slowly, picking up momentarily and then falling off for a longer period, there is a corresponding variation in the potential, causing the cut-out to operate intermittently. This is a condition that seldom occurs and results in no harm when it does.

Q. When the ammeter or indicator flutters in the same manner with the engine running at medium or at high speed, what does it indicate?

A. That there is a loose connection between the generator and the cut-out, or an intermittent short-circuit or ground caused by a chafed wire alternately making contact with some metal part owing to the vibration. It is much more likely to be simply a loose connection and will be found most often on the back of the cut-out itself. This should be remedied at once. If neglected, it will cause abnormal wear of the platinum points in the cut-out.

Q. When the ammeter does not indicate "Charge" though the engine is speeded up, but does register a discharge when the lights are turned on and the engine is idle, what is the nature of the trouble?

A. Either the generator is not producing current or the regulator (where an external type is employed) is not working properly. The generator brushes may not be making proper contact with the commutator, or there may be a loose, corroded, or broken connection in the generator cut-out battery circuit. Where a belt drives the generator, it may be too loose to run the machine at its proper speed.

Q. When the ammeter gives no charging indication though the lamps are off and the engine is speeded up, and gives no discharging indication though the engine is idle and lamps are switched on, what is likely to be the cause?

A. There is an open or a loose connection in the battery circuit or in the battery itself. The ammeter may be at fault. See that its indicating pointer has not become jammed nor dropped off its bearings.

Q. In case the ammeter indicates "Discharge" though the engine be idle and all lights turned off, what is the trouble?

A. There is a short-circuit or a ground somewhere in the lighting circuits or between the battery and the ammeter, as the discharge reading in such circumstances indicates a leakage of current; or the cut-out has failed to operate and still has the battery in circuit with the generator, though the engine is stopped. The ammeter pointer may be bent.

Q. When the meter indicates a charge though the engine is at rest, what is the nature of the fault?

A. The ammeter pointer has become bent or deranged so that it is stuck fast in place, showing a charge.

Q. When the ammeter charge indications are below normal, what is apt to be the cause?

A. The generator commutator or brushes may need attention, such as cleaning or sanding-in, or new brushes may be necessary. The generator speed may be too low; in case of belt drive, it may not be getting the benefit of the full speed of the engine owing to a slipping belt. The regulator (external type) may not be functioning properly, or there may be an excessive lamp load on the generator.

Q. When the ammeter charge reading is above normal, what is likely to be the cause?

A. There may be a short-circuited cell in the battery, or a short in the charging circuit, or the regulator (external type) may not be working properly.

Q. What will cause the discharge reading of the ammeter to become abnormally high?

A. The lamp load may be excessive, as where higher candle-power bulbs are used, or more lights than originally intended are put in the circuit. There may be leakage in some part of the lighting Circuit, or the cutout contacts may be stuck together, permitting a discharge through it or through the generator.

ELECTRIC GEAR-SHIFT

Q. What is the operating principle upon which the electric gear-shifting mechanism is based?

A. That of the solenoid and its attraction for its core when a current is passed through its winding.

Q. What is the source of current supply for the electric gear-shift?

A. The storage battery of the lighting system. The operation of gear-shifting is carried out so quickly that only a nominal additional demand is made on the battery.

Q. How is the electric gear-shift controlled?

A. By a series of buttons corresponding to the various speeds and located on the steering wheel, and by a master switch..

Q. What is the object of the buttons, and what are they termed?

A. To partly close the circuit to the particular solenoid of the speed desired. They are termed "selector switches" since they permit selecting in advance the speed desired.

Q. Why is a master switch employed, and why is it so called?

A. To avoid the complication which would otherwise result from the necessity of providing two switches for each change of speed, i.e., a selector switch and an operating switch. It is termed a master switch because it controls the current supply to all of the circuits.

Q. Why is a neutral button provided in addition to the buttons for the various speeds on the selector switch?

A. To return any of the selector buttons to neutral without the necessity of going through that speed in case it is not desired to engage the speed in question after the button has been pushed. Also to open any of the selector switches that may be closed when it is desired to stop.

Q. What is the neutralizing device?

A. It is a mechanism incorporated with the shifting mechanism to open the master switch automatically after the gears have been engaged.

Q. Why is the neutralizing device necessary?

A. If it were not provided, the master switch would remain closed, causing a constant drain on the battery and rendering the mechanism inoperative after one shift had been made.

Q. How many solenoids are provided in the standard three-speed and reverse gear box?

A. One for every movement necessary.

Q. Is the current sent through a solenoid in one direction to pull the shifting bar into it and then in the opposite direction to move the bar the other way?

A. No, the current is not reversed through the same solenoid. After the left-hand solenoid, operating the first-speed gear, for example, has pulled the shifter bar to the left, a second solenoid, on the opposite end of the same bar, is energized to pull it back to the right, to shift to second or intermediate.. The current is sent through a different solenoid by means of the selector switches for each shift desired.

Q. When the electric gear-shift failed to operate, where would be the most likely place to look for the cause of the trouble?

A. First see that the battery is not exhausted, then that no connections between the battery and the terminal block have parted, thus cutting off the current supply. The wiring is so simple and so strongly protected that it is very unlikely to have anything happen to it except at the connections. This is likewise true of the solenoids.

Q. In case the battery is amply charged and nothing is wrong with the connections, what procedure should be followed?

A. Use the lamp-testing set described in connection with the lighting and starting systems and test out the various circuits as shown on the wiring diagram. In using this test, it must always be borne in mind that touching the two points to the same or connecting pieces of wire or metal will always cause the lamp to light. It is useful in this way for indicating the continuity of a wire, i.e., that it has not broken under the insulation, but, until experience has been gained in its use, it will be nothing unusual to find that the points have been touched to connecting pieces of metal which have no relation to the circuit. As such metal will complete the circuit through the lamp, the latter will light, but without indicating anything of value to the trouble hunter. Always test the lamp itself before proceeding. It may have become partly unscrewed in its socket or its filament may have been broken.

BATTERY

Electrolyte

Q. Why is it necessary to refill the battery jars at regular intervals?

A. Because the heat generated in the cells evaporates the water from the electrolyte, and, if the latter is permitted to fall below the tops of the plates, they will dry out where they are exposed, and the heat of charging will then cause them to disintegrate, ruining the battery.

Q. Why should this be done at intervals of not less than two weeks?

A. Because the limited amount of electrolyte permitted by the restricted size of the cells over the plates—usually one-half inch—will be evaporated in that period by a battery that is in more or less constant use.

Q. Why should water alone and never acid or electrolyte be used to make up this loss?

A. Only the water evaporates, so that if either acid or fresh electrolyte is added, it will disturb the specific gravity of the solution in the cells and totally alter their condition.

Q. What is the reason that battery manufacturers insist that only distilled water or its nearest equivalent, rain water or melted artificial ice, be used for this purpose?

A. Because ordinary water contains impurities that are apt to harm the plates, such as iron salts, or alkaline salts that will affect both the plates and the electrolyte.

Q. What should be done to a battery that has had its efficiency impaired by being filled with impure water?

A. The cells should be taken apart, the separators discarded, the plates thoroughly washed for hours in clean running water without exposing them to the air where they would dry, the jars washed out, the plates reassembled with new separators, the jars filled with fresh electrolyte of the proper specific gravity, and the battery put on a long slow charge from an outside charging source, i.e., not on the car itself. Unless there are proper facilities for carrying this out, it will be preferable to ship the battery back to the maker so that it can be given proper treatment, particularly as it is necessary to reseal the cells.

Q. How is electrolyte prepared?

A. By adding pure sulphuric acid a very little at a time to distilled water until the proper specific gravity is reached, and then permitting the solution to cool before using. The mixture must always be made in a porcelain, hard rubber, or glass jar; never in a metal vessel. Commercial sulphuric acid or vitriol should not be employed, as it is far from pure. Never add water to acid. When the two are brought together, their chemical combination evolves a great amount of heat, and the acid will be violently spattered about.

Q. How often should distilled or rain water be added to the cells?

A. This will vary not alone with different systems but with different cars equipped with the same system, owing to the difference in conditions of operation. The only way to determine this definitely is to inspect the cells at short intervals and note how long they will operate before the electrolyte gets close enough to the tops of the plates to require additional water. This may be a week, ten days or two weeks, or even more, if the car is not run much.

Q. When a battery requires the addition of water at very short intervals to keep the level of the electrolyte one-half inch above the plates, what does this indicate?

A. It shows that the battery is being constantly overcharged, which keeps it at a high temperature, causing excessive evaporation. This will usually occur where a car is in constant use during the day but is driven very little at night. It may be remedied by adjustment of the regulation so as to reduce the output of the generator. Where this is not possible, as in the case of simple bucking-coil regulation which is entirely self-contained and permits no variation, additional resistance may be introduced in the generator-battery circuit. This may take the form of a small-resistance unit consisting of German silver or other high-resistance wire wound on a porcelain tube and mounted on the forward side of the dash. A single-pole knife switch should be placed in the circuit with the resistance so that the latter can be cut in or out of the generator circuit as circumstances may require.

Q. With conditions as in the preceding question, how can the amount of resistance to be inserted in the circuit be figured?

A. By the use of Ohm's law. In this case, it would be $R=\frac{E}{C}$, or resistance equals voltage divided by current. How much resistance to use can only be answered by the conditions of operation. Where a car is used steadily during the day and very seldom at night, it may be necessary to reduce the charge by two-thirds. In the case of a 6-volt system normally charging at 12 amperes, the generator delivers current at 7 to $7\frac{1}{2}$ volts in order to overcome the voltage of the battery when fully charged. Selecting 7 volts, we see that the resistance in circuit when the current is 12 amperes is $7\div12$, or .6 ohm approximately. Now when the charging current is 4 amperes, we must have $7\div4$, or 1.75 ohms in circuit; that is, to reduce the current from 12 to 4 amperes, a resistance of $1.75-.6$, or 1.15 ohms must be inserted. The amount of resistance wire necessary to give this resistance or any other resistance necessary may be found in tables of wire sizes and resistances of special wire employed for this purpose. The wire is bare and must be wound on the tube so that adjacent coils do not touch. An extreme instance is cited here. It may be necessary in many cases to reduce the charging rate by a very much smaller fraction. Ordinarily the charging rate should not be altered.

Q. When the battery is constantly gassing, or "boiling", as the car owner usually puts it, what is the trouble?

A. It is being constantly overcharged. This will greatly reduce the life of the battery, and the charging rate should be reduced, as mentioned in the preceding answer. It is essential that the battery be kept fully charged; but if it is continually overcharged, this will keep the cells at an abnormal temperature which is injurious to the plates. The battery treatment will vary with the season, for the demand on it is much heavier during cold weather than in summer.

Hydrometer Tests

Q. Why should the battery be tested with the hydrometer at regular intervals of a week or so?

A. Because the specific gravity of the electrolyte is the most certain indication of the battery's condition.

Q. What should the hydrometer read when the battery is fully charged?

A. 1.280 to 1.300.

Q. What point is it dangerous to permit the specific gravity of the electrolyte to fall below, and why?

A. 1.250; because below this point, the acid begins to attack the plates and the battery plates sulphate. The lower the specific gravity, the faster sulphating takes place.

Q. What should be done when the hydrometer reading is 1.250 or lower?

A. The battery should be put on charge immediately, either by running the engine or by charging from an outside source of current until the gravity reading becomes normal.

Q. If the hydrometer reading of one cell is lower than that of the others, what should be done?

A. Inspect the cell to see if the jar is leaking; note whether electrolyte is over the plates to the depth of ½ inch and whether the electrolyte is dirty. If these causes are not apparent, the cell will have to be opened and inspected for short-circuits from an accumulation of sediment in the bottom of the jar or from buckling of the plates.

Q. Are hydrometer tests alone conclusive?

A. No. To be strictly accurate, they should be checked by voltage tests, in addition.

Q. How should these voltage readings be taken?

A. With the aid of a portable voltmeter, using the low-reading scale, i.e., 0-3 volts, and always with the battery discharging, the load not exceeding its normal low discharge rate.

Q. Why should the test not be made with the starting-motor load?

A. Because the discharge rate while the starting motor is being used is so heavy that even in a fully charged battery in good condition it will cause the voltage to drop rapidly.

Q. Why should the voltage readings not be taken while the battery is charging?

A. Because the voltage of the charging current (always in excess of six volts) will cause the voltage of a battery in good condition to rise to normal or above the moment it is placed on charge, such readings are not a good indication of the battery's condition.

Q. What should the voltage of the cells be?

A. In any battery in good condition, the voltage of each cell at the battery's normal low discharge rate (5 to 10 amperes, as in carrying the lamp load) will remain between 2.1 and 1.9 volts until it begins to approach the discharged condition. A voltage of less than 1.9 volts per cell indicates either that the battery is nearly discharged or that it is in bad condition. The same state is also indicated when the voltage drops rapidly after the load has been on a few minutes.

Joint Hydrometer-Voltmeter Test

Q. What should the hydrometer and voltmeter readings be for a fully charged battery in good condition?

A. Hydrometer 1.275 to 1.300; voltage 2 to 2.2 volts per cell.

Q. What does a hydrometer reading of 1.200 or less with a voltage of 1.9 volts or less per cell indicate?

A. This shows that excess acid has been added to the electrolyte. Under these conditions, the lights will burn dimly even though the hydrometer test alone would appear to show that the battery is more than half charged.

Q. What does a hydrometer reading in excess of 1.300 indicate?

A. It indicates that an excessive amount of acid has been added to the electrolyte, regardless of whether the voltage reading is high, low, or normal.

Q. Where a low voltage reading is found, how can it be determined whether the battery is in bad condition or merely discharged?

A. Stop the discharge by switching off the load (lamps) and put the battery on charge, cranking the engine by hand. After a few minutes of charging, note whether the voltage of each cell promptly rises to 2 volts or more. Any cells that do not are probably short-circuited or otherwise in bad condition.

Q. How can a rough test of the condition of the battery be made without the use of any instruments?

A. On systems fitted with a battery cut-out in the generator battery circuit, remove the cover of the cut-out (the generator being stationary) and momentarily close the cut-out points with the finger. The discharge shown by the ammeter the monent the points are closed should be anywhere from 10 to 20 amperes, differing, of course, with different systems. In any case, it should be equal to or greater than the maximum normal output of the generator, provided the battery is at least three-quarters charged.

Q. What effect will allowing the electrolyte to fall too low in the cells have, apart from the damage that it will cause to the plates?

A. It will tend to increase the voltage if the battery is otherwise in good condition, and this may be carried to a point where it will burn out the lamps.

Q. What is meant by "floating the battery on the line"?

A. This describes the relation of the battery to the generator and lighting circuits in systems where the current for lighting is taken directly from the generator when running, any excess over the requirements of the lamps being absorbed by the battery. The moment the generator speed falls below the point where it supplies sufficient current to supply all that is needed for the lamps, the battery automatically supplies the balance. When the generator is idle, the battery, of course, supplies the current for lighting as well as for starting.

Gassing

Q. Why should the cell tops be wiped dry from time to time and the latter as well as the terminals be washed with a weak solution of ammonia and water?

A. As the charge approaches completion, the cells gas; when overcharged they gas very freely. This gas carries with it in the form of a fine spray some of the electrolyte, and the acid of the latter will attack the terminals and corrode them. Wiping clean does not remove this acid entirely, so the ammonia solution is necessary to counteract its effect, the ammonia being strongly alkaline.

Q. Why should an unprotected light, i.e., any flame or spark, not be allowed close to a storage battery?

A. Because the gas emitted by the battery on charge is hydrogen, which is not only highly inflammable but, when mixed in certain proportions with air, forms a powerful explosive mixture.

Q. What is the cause of gassing?

A. When a battery is charged, the water of the electrolyte is decomposed by the current into gases. During the early part of the charge these gases unite with the active material of the plates, but as the charge proceeds, more gas is evolved than the plates can take care of and it bubbles up through the electrolyte. This is known as the gassing point, and the temperature of the cell also begins to rise at that point.

Q. Is gassing harmful to the battery?

A. The greatest wear on the positive plates takes place during the gassing period, and, if carried too far, they may be injured by reaching a dangerous temperature (105° F., or over) which will tend to loosen the active material.

Q. How can gassing be checked?

A. By cutting down the charge. In some systems this can be effected by the insertion of extra resistance provided for the purpose. Where this cannot be done and it is necessary to keep the car running, turn on all the lamps or start the engine once or twice to reduce the charge of the battery. As the lamps usually consume 80 to 95 per cent of the generator output, they should be sufficient to prevent a further overcharge.

Q. Can the generator be disconnected from the battery to prevent overcharge?

A. Not unless it is short-circuited, as directed in the instructions covering different systems. Otherwise, it will blow its field fuse or, where one is not provided, burn out its windings, except in cases where special provision is made to guard against this.

Sulphating

Q. Why must a battery never be allowed to stand in a fully discharged state?

A. Because the acid of the electrolyte then attacks the plates and converts the lead into white lead sulphate which is deposited on them in the form of a hard coating that is impenetrable to the electrolyte, so that the plates are no longer active. The battery then is said to be *sulphated*.

Q. Can a sulphated battery be put in good condition, and what treatment must be given it to do so?

A. If the sulphating has not gone too far, the battery may be brought back to approximately normal condition by a long heavy charge at a higher voltage than ordinary. Where the battery has become badly sulphated, it is preferable to remove it from the car and charge from an outside source of current, as it may require several days to complete the process. (Note instructions regarding the running of the generator when disconnected from the battery, as otherwise it may be damaged.) If avoidable, the car should not run with the battery removed. If the battery has not stood discharged for any length of time, the charge may be given on the car by running steadily for 8 to 10 hours with all lights off. No lamps must be turned on, as the increased voltage is liable to burn them out.

Voltage Tests

Q. What is the purpose of the voltmeter in connection with the battery?

A. It is chiefly useful for showing whether a cell is short-circuited or is otherwise in bad condition.

Q. Can the voltmeter alone be relied upon to show the condition of the cells?

A. No; like the hydrometer, its indications are not always conclusive, and it must be used in conjunction with the hydrometer to insure accuracy.

Q. What type of voltmeter should be employed for making these tests?

A. For garage use, a reliable portable instrument with several connections giving a variable range of readings should be employed. For example, on the 0-3 volt scale, only one cell should ever be tested; attempting to test any more than this is apt to burn out the 3-volt coil in the meter. The total voltage of the number of cells tested should never exceed the reading of the particular scale being used at the time, as otherwise the instrument will be ruined.

Q. Must these readings be particularly accurate?

A. Since a variation as low as .1 volt (one-tenth of a volt) makes considerable difference in what the reading indicates as to the condition of the battery, it will be apparent that the readings must not only be taken accurately, but that a cheap and inaccurate voltmeter is likely to be misleading rather than helpful.

Q. What precautions should be taken before using the voltmeter?

A. Always see that the place on the battery connector selected for the contact is bright and clean and that the contact itself is firm, otherwise the reading will be misleading since the increased resistance of a poor contact will cut down the voltage.

Q. How is the instrument connected to the battery?

A. The positive terminal of the voltmeter must be brought in contact with the positive terminal of the battery and the negative terminal of the voltmeter in contact with the negative terminal of the battery.

Q. In case the markings on the battery are indistinct, how can the polarity be determined?

A. Connect the voltmeter across any one cell. Should the pointer not give any voltage reading, butting against the stop at the left instead, the connections are wrong and should be reversed; if the instrument shows a reading for one cell, the positive terminal of the voltmeter is in contact with the positive terminal of the battery. This test can be made without any risk of short-circuiting the cell, since the voltmeter is wound to a high resistance and will pass very little current. Such is not the case with the meter, which should never be used for this purpose.

Q. When the battery is standing idle, what is the cell voltage and why is this not a good test?

A. Approximately two volts, regardless of whether the battery is fully charged or not. Voltage readings taken when the battery is on open circuit, i.e., neither charging nor discharging, are only of value when the cell is out of order.

Q. If the battery is in good condition and has sufficient charge, what should the voltmeter reading show?

A. Using the lamps for a load, the voltage reading after the load has been on for five minutes or longer should be but slightly lower (about .1 volt) than if the battery were on open circuit.

Q. When one or more cells are discharged, what will the reading show?

A. The voltage of these cells will drop rapidly when the load is first put on and sometimes even show reverse readings, as when a cell is out of order.

Q. What will the voltmeter indicate when the battery is nearly discharged?

A. The voltage of each cell will be considerably lower than if on open circuit after the load has been on for five minutes or more.

Q. How can the difference be distinguished between cells that are merely discharged and those that are in bad condition?

A. Put the battery on charge, cranking the engine by hand to start, and test again with the voltmeter; if the voltage does not rise to approximately 2 volts per cell within a short time, it is evidence that there is internal trouble which can be remedied only by dismantling the cell.

Q. What effect has the temperature on voltage readings?

A. The voltage of a cold battery rises slightly above normal on charge and falls below normal on discharge. This last is one of the chief reasons for its decreased efficiency in cold weather.

Q. What is the normal temperature of the battery and to what does this refer?

A. The normal temperature of a battery is considered at 70° F., but this refers to the temperature of the electrolyte in the battery as shown by a battery thermometer and not to the temperature of the surrounding air. If the battery has been charging at a high rate for some time, it may be normal even though the weather be close to zero at the time.

Sediment

Q. What is the cause of sediment or mud accumulating in the jars, and why must it be removed before it reaches the bottoms of the plates?

A. This sediment consists of the active material of the plates, which has been shaken out, due to the loosening caused by the charging and discharging, and aggravated by the constant vibration. It must never be allowed to reach the plates, as it is a conductor and will short-circuit them and thus ruin the battery.

Q. How long will a battery stay in service before this occurs?

A. This depends on the type of jar employed and the treatment that the battery has received. If it has been kept constantly overcharged, or if discharged to exhaustion in a very short period, as by abuse of the starting motor when the engine is not in good starting condition, or if it has been subjected to short-circuits by grounding or by dropping tools on its terminals, the plates will disintegrate much quicker than where proper treatment has been given it. With the old-style jar, only an inch or so is allowed to hold this accumulation of sediment below the plates, while in later types fully 3 inches or more are allowed in the depth of the cell for this purpose. A battery with jars of the latter type that has been cared for properly should not require washing out under two years. The procedure is the same as that given for removing the effects of impure water. The plates must never be allowed to dry.

Washing the Battery

Q. What is meant by washing the battery, and why is it necessary?

A. Washing a battery involves cutting the cells apart, washing the elements and the jars, and reassembling with new separators and new electrolyte. It is necessary to prevent the accumulation of sediment, consisting of active material shaken from the plates, to a point where it will touch them and thus cause a short-circuit.

Q. How often is it necessary to wash a battery?

A. This will depend on the type of cell in the battery and the age of the latter. If the battery has the modern-style jar with extra deep mud space, it probably will not be necessary to wash it until it has seen two to three seasons' use. With the older form of cell in which the space allowed for sediment is much less, washing doubtless will be necessary at least once a season. As the battery ages, it will be necessary to wash it oftener.

Q. What other causes besides the type of jar and the age of the battery influence the frequency with which it is necessary to wash the battery?

A. The treatment the battery has received. If it has been abused by overcharging and permitting the cells to get too hot, the active material will be forced out of the grids much sooner.

Q. How can the necessity for washing be determined?

A. The presence of one or more short-circuited cells in a battery that has not been washed for some time will indicate the necessity for it. Each cell should be tested separately with the low-reading voltmeter; a short-circuited cell will either give no voltage reading or one much below that of the others. Cut such a cell out and open it; if the short-circuit has been caused by an accumulation of sediment, the others most likely are approaching the same condition.

Q. How is a battery washed?

A. By cutting the cells apart, unsealing them, and lifting out the elements which should be immersed immediately in a wooden tub of clean pure water. The separators then are lifted out and the positive and negative groups of plates separated, but they must be marked so that the same groups may go back in the right cells. Before disposing of the old electrolyte, its specific gravity should be noted, as new electrolyte of the same density must be used. The plates should be washed in copious running water for several hours, but their surfaces must never be exposed to the air. Reassemble with new separators, fill the jars with fresh electrolyte of the same specific gravity as that discarded, and keep the elements under water until ready to place in the jars, which then should be sealed and the lead connectors burned together again.

Give a long slow charge after reassembling. The battery will not regain its normal capacity until it has been charged and discharged several times.

Connectors

Q. Why should lead connectors be employed, and why is it necessary to burn them together?

A. Any other metal will corrode quickly. Burning is necessary to make good electrical connection, except where bolted connectors are employed.

Q. When connections have become badly corroded or broken, what should be done with them?

A. They should be replaced with new lead-strap connectors supplied by the makers. If they are not obtainable and the battery must be in service meanwhile, the old ones can be cleaned by cutting away the corroded parts and burning new lead on them to bring them to normal size. If broken, burn together with lead in the same way. Heavy copper cable can be used temporarily but must be removed as soon as possible, as it will corrode quickly. Never use any other metal except lead or copper and never use light copper wire. It will either be burned up in a flash or it will cut down the amount of current from the battery, thus causing unsatisfactory operation.

Buckled Plates

Q. What is the cause of badly disintegrated or buckled plates?

A. Sudden discharge due to a short-circuit or to constant abuse of the starting motor on an insufficiently charged battery.

Q. Is there any remedy for such a condition?

A. If the plates are not badly buckled and have not lost much of their active material, the cells may be put in service again by washing and reassembling as described, but if there is any considerable loss of active material, new plates will be necessary.

Low Battery

Q. What are the indications of a low battery?

A. The starting motor fails to turn the engine over, or does so very slowly, or only a part of a revolution. The lights burn very dimly. The hydrometer shows a specific-gravity reading of 1.250 or less. Voltmeter test shows less than 5 volts for a 3-cell battery (for greater number of cells, in proportion), or 1.75 volts or less for each cell.

Q. What are the causes of a low battery?

A. The electrolyte not covering the plates, or being too weak or dirty. A short-circuit in the battery due to the accumulation of sediment reaching the bottom of the plates. An excessive lamp load, all lights being burned constantly with but little daylight running the car. Generator not charging properly.

Specific Gravity; Voltage

Q. What are the specific gravity and voltage of fully discharged and fully charged cells?

A. Total discharge: 1.140 to 1.170 on the hydrometer; and 1.70 to 1.85 volts on the voltmeter. Fully charged: 1.276 to 1.300 specific gravity; 2.35 to 2.55 volts.

Q. Are these readings always constant for the same conditions?

A. No. The charging voltage readings will vary with the temperature and the age of the cell; the higher the temperature and the older the cell the lower the voltage will be. Hydrometer readings also depend on the temperature to some extent. For every ten degrees Fahrenheit rise in temperature, the specific gravity reading will drop .003 or three points, and *vice versa.*

Q. Under what conditions should voltage tests be made?

A. Only when the battery is either charging or discharging. Readings taken when the battery is idle are of no value.

Q. Under what conditions should hydrometer tests be made?

A. The electrolyte must be half an inch over the plates and it must have been thoroughly mixed by being subjected to a charge. Hydrometer readings taken just after adding water to the cells are not dependable.

Q. When should acid be added to the electrolyte?

A. As the acid in a battery cannot evaporate, the electrolyte should need no addition of acid during the entire life of the battery under normal conditions. Therefore, if no acid has leaked or splashed out and the specific gravity is low, the acid must be in the plates in the form of sulphate and the proper specific gravity must be restored by giving the battery an overcharge at a low charging rate.

Q. What does a specific gravity in some cells lower than in others indicate?

A. Abnormal conditions, such as a leaky jar, loss of acid through slopping, impurities in the electrolyte, or a short-circuit.

Q. How can it be remedied?

A. Correct the abnormal conditions, and then overcharge the cells at a low rate for a long period, or until the specific gravity has reached a maximum and shows no further increase for 8 or 10 hours. If, at the end of such an overcharge, the specific gravity is still below 1.270, add some specially prepared electrolyte of 1.300 specific gravity. Electrolyte should not be added to the cells under any other conditions.

Q. Is an overcharge beneficial to a battery?

A. The cells will be kept in better condition if a periodical overcharge is given, say once a month. This overcharge should be at a low rate and should be continued until the specific gravity in each cell has reached its maximum and comparative readings show that all are alike. To carry this out properly will require at least 4 hours longer than ordinarily would be necessary for a full charge. If the plates have become sulphated due to insufficient charging, it may be necessary to continue the overcharge for 10 to 15 hours longer. Should the specific gravity exceed 1.300 at the end of the charge, draw off a small amount of electrolyte with the syringe from each cell and replace with distilled water. If below 1.270, proceed as mentioned above for addition of acid.

Charging from Outside Source

Q. What is meant by charging from an outside source?

A. A source of direct current other than the generator on the car.

Q. Why is it necessary to charge the battery from an outside source?

A. When the battery has become sulphated, has been standing idle for any length of time, or has been run down from any other cause so that it is out of condition, a long charge at a uniform rate is necessary, and it would seldom be convenient to run the car for 8 or 10 hours steadily simply to charge the battery; frequently, a longer charging period than this is necessary.

Q. How is charging from an outside source effected?

A. This will depend upon the equipment at hand and the nature of the supply, i.e., whether alternating or direct current. If the current is alternating, a means of converting it to direct current is necessary, such as a motor-generator, a mercury-arc rectifier, chemical or vibrating type of rectifier. These are mentioned about in the order of the investment involved. In addition, a charging panel is needed to complete the equipment, this panel being fitted with switches, voltmeter, and ammeter, and a variable resistance for regulating the charge. Where direct-current service is obtainable at 110 or 220 volts, the rectifier is unnecessary.

Q. How can a battery be charged from direct-current service mains without a special charging panel?

A. By inserting a double-pole single-throw switch and 10- or 15-ampere fuses on taps from the mains and ordinary incandescent lamps in series with the battery to reduce the voltage, Fig. 409.

Q. How many lamps will be needed?

A. This will depend upon their character and size, as well as upon the amount of charging current necessary. For a 10-ampere charge for a 6-volt storage battery, seven 110-volt 100-watt (32 c.p.) carbon-filament lamps, or their equivalent, will be needed; i.e., fourteen 110-volt 50-watt (16 c.p.) carbon-filament lamps; eighteen 110-volt 40-watt tungsten lamps, or twenty-eight 110-volt 25-watt tungsten lamps. For a 12-volt or 24-volt battery the number of lamps will have to be decreased in proportion in order not to cut the voltage of the supply current below that of the battery. For 220-volt d.c. supply mains, if a three-wire system is employed, the taps should be taken from the center wire and one outside wire; this will give 110 volts. If the service is 220-volt two-wire, more lamps will be needed to reduce the voltage, which should exceed that of the battery by only 1½ to 2 volts except where a high voltage charge to overcome sulphating is being given, in which case it may be slightly higher.

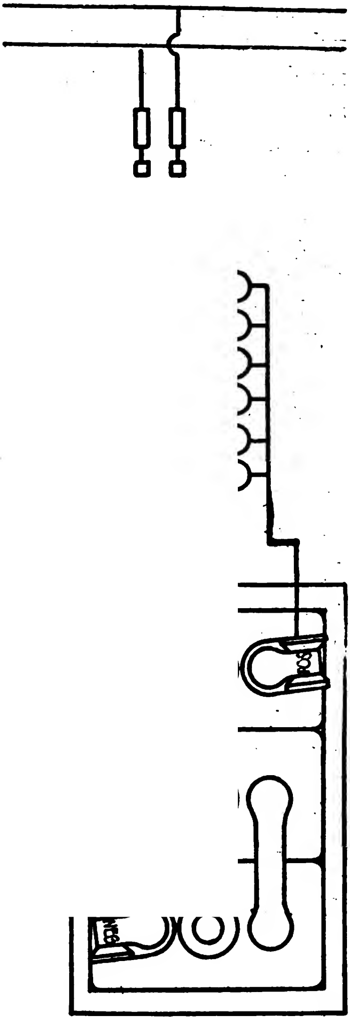


Fig. 409. Diagram of Connections for Charging Six-Volt Storage Battery from Lighting Circuit

Q. Where no outside source of current is available, or where no rectifier is at hand to convert alternating current, how can the battery be given the long charge necessary?

A. Run the engine. Supply it with plenty of oil and provide hose connections from the water supply to the filler cap on the radiator and a drain from the lower petcock. Open the latter and turn on just sufficient water to keep the engine reasonably cool; increase if necessary as it runs hotter.

Q. What precaution must be taken always before putting the battery on charge from an outside source?

A. The polarity of the circuit must be tested in order to make certain that the battery will be charged in the proper direction.

Q. How can this be done?

A. If a suitable voltmeter is at hand, i.e., one of the proper voltage for the 110-volt current, connect it to the mains. If the needle does not move over the scale but shows a tendency to butt against the stop pin at the left, reverse the connections. The needle will then give a proper reading and the positive connection to the meter must be used for the positive side of the battery. Should no voltmeter of the right voltage be available, connect two short wires with bared ends to the fused end of the switch. Dip the bared ends of the wire in a glass of water, being careful to keep them at least an inch part. When the switch is closed, fine bubbles will be given off by the wire connected to the negative side. The battery terminals are stamped *Pos.* and *Neg.*, and the connections should be made accordingly.

Intermittent and Winter Use

Q. What should be done with an idle battery?

A. If it is to be idle for any length of time, as where the car is to be stored, it should be given a long overcharge as described above before being put out of service. Fill the cells right to the top with distilled water to allow for evaporation and absorption of acid by the plates. Give the battery a freshening charge at a low rate once a month. Discharge the battery and re-charge before putting it into service again. If it has stood out of service for a long period, the battery will be found at a low efficiency point and will not reach its maximum capacity again until it has had several charges and discharges.

Q. Does cold weather have any effect on the storage battery?

A. It causes a falling off in its efficiency. If not kept charged, the electrolyte will freeze under the following conditions: battery fully discharged, sp. gr. 1.120,20° Fahrenheit; battery three-quarters discharged, sp. gr. 1.160, temperature zero; half discharged, sp. gr. 1.210, 20 degrees below zero; one quarter discharged, sp. gr. 1.260, 60 degrees below zero. When storing away for the winter, the battery must either be kept charged or put where the temperature does not go lower than 20 degrees above zero.

Edison Battery

Q. Is it ever necessary to wash out an Edison battery?

A. No. The cells are permanently sealed, as the active material cannot escape from its containers.

Q. Do all of the foregoing instructions apply to the Edison as well as to the lead-plate battery?

A. No. The Edison requires very little attention, practically the only care necessary being to keep the cars replenished with distilled water at intervals.

Charging rates for Edison cells are given in the article on Electric Automobiles. S.A.E.-standard instructions for lead-plate cells are also given in the same article.

DELCO DISTRIBUTOR FOR PACKARD "TWELVE" ENGINE
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

ELECTRICAL REPAIRS

FORD MAGNETO

Description. The Ford magneto consists of a stationary spider, on which are placed sixteen coils of flat copper ribbon, each coil wound in the opposite direction to the next and the whole assembly connected in series, thus making the coils alternately north and south poles. One end of this coil circuit is grounded through a copper rivet in the spider, and the other end is soldered to a terminal block at the top of the spider. The current is carried out through a terminal post on the flywheel cover by means of a pointed spring attached to the post and bearing on the terminal block.

The magnetic field is produced by sixteen magnets fastened to the rim of the flywheel. The magnets are placed with their north poles together and their south poles together. Over each pole thus formed is placed a flat iron pole piece. The magneto is assembled with a $\frac{1}{32}$-inch clearance between the magnets and coils, and this clearance is adjusted by means of metal shims. Fig. 410 shows the coils.

Fig. 410. Copper Ribbon Coils of Ford Magneto

Capacity. As this magneto has no commutator the current produced is alternating, with sixteen reversals per revolution. The voltage produced is from 6 to 30, depending upon the load and the speed. The ignition requires 1 ampere and the headlights about 3; as this magneto was designed to take care of this load only, an increased load on the magneto is inadvisable. Numerous devices have been made to charge a battery from this magneto, but the majority of these devices are unsatisfactory owing to an insufficient current capacity to offset the rectifying losses.

Testing. Through use, the current is decreased either by weak magnets or by partial grounds in the coils. In making a test with an alternating voltmeter, the voltage is taken with the engine running at a car speed of about 25 miles per hour. With the ignition only as a load, the voltmeter should show about 20 volts when the magneto is up to strength.

Recharging. When the magnets become weak, it is necessary to recharge or replace them. They may be recharged without removing them from the car, with the flywheel off but with the magnets still attached, or with the magnets removed from the flywheel; new magnets may be used.

Recharging in Car. Recharging in the car is done by sending a current through the coils, causing each coil to become a separate magnet charger, charging each magnet which is placed opposite to it. As it takes direct current to charge a magnet properly, there must be a direct current supply. Two 6-volt starting batteries may be satisfactory to use, the connections being made between the batteries and the magneto with No. 6 wire. In order to saturate the magnets, 40 amperes should flow through the coils. Since about 1917 the resistance of the Ford magneto coils has been 0.25 ohm. Applying 12 volts to the coil from two storage batteries connected in series will allow 48 amperes to flow through the coils.

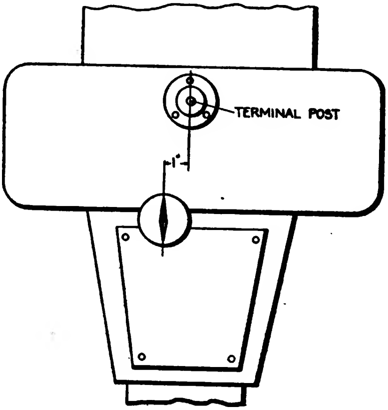


Fig. 411. Position of Compass

Before the current is applied to the magneto, the flywheel must be set in proper relation to the coils. This is done by putting a compass over the flywheel, Fig. 411. Take out the forward floor boards; disconnect all wires from the terminal post; place the compass slightly back and 1 inch to the left of the post; raise the left-hand side of the hood so that the compass will be in sight while cranking. Then crank the engine slowly until the compass needle points with the north to the front of the car. It is well to shake the compass a little after it is pointing straight to be sure of a correct reading. Now place the positive battery wire with the clip on the terminal post, and then touch the large nut on the exhaust pipe several times with the lead. Do not hold the contact more than a second as it may burn off a connection on the inside of the magneto because of the heavy flow of current.

The first application of the current charges the magnets, but several applications give the owner, who may be a spectator, the assurance of a job well done. Remove the charging wires and replace the ignition wire on the terminal post, then connect the test instrument and note the rise in strength. In some cases it will be found that the magneto is weaker or entirely dead; this may be due to any one of four causes:

Poor setting of magnets with compass
Reverse setting
Polarity of charging current reversed
Magneto coil connections reversed

The first condition is caused by the needle of the compass sticking, thus giving a false reading; therefore, reset and charge again. If it fails to come up, reverse the setting; that is, set with the south pole up instead of the north pole as in the original setting.

The second condition is generally caused by the compass needle becoming reversed; therefore, recharge the compass needle correctly on the magnet charger, and be sure that the dark end of the needle points north. To correct this second condition, reverse the setting of the magneto as before described and again charge.

To remedy the third condition, test the polarity of the charging wires; if it is reversed, change back and charge again, first reversing the setting.

The fourth condition seldom arises and is generally hard to locate. It is caused by the coils being improperly connected at the factory, that is, they are connected in the opposite direction. The remedy is to reverse the setting and again charge.

In some cases the magnetism has practically disappeared; then the only remedy is to charge in any position and continue the charging process until a polarity is found.

Recharging on Flywheel. In recharging without removing from the flywheel, it is handy to use a small 6-volt charger having Ford charging pole pieces. Find the north pole of the charger and mark it with chalk; then find the north pole of the magnets and mark; place the north pole of the charger to the south pole of the first magnet and apply the current for one second. Skip the next magnet, as that is of opposite polarity; go around the wheel and charge the seven other magnets of the same polarity as the first magnet. Now reverse the wires on the charger, and charge the remaining magnets in like manner.

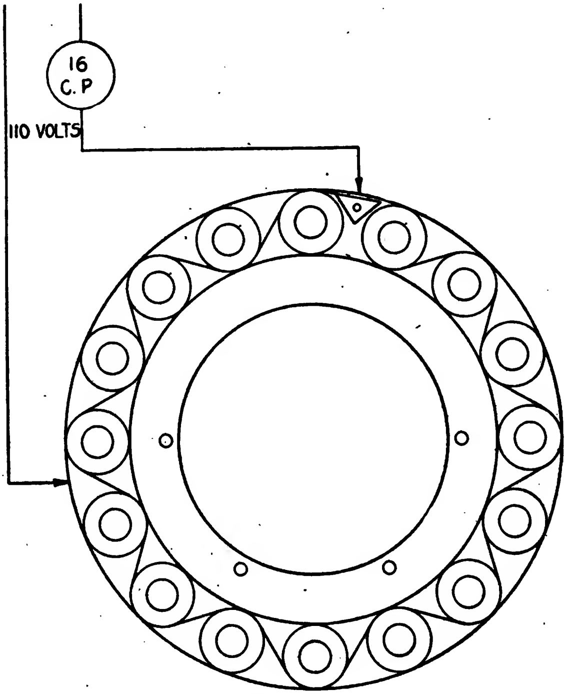


Fig. 412. Testing Coils for Grounds

Recharging out of Car. If the magnets are removed from the flywheel, the first operation is to sort out the right- and left-hand magnets and place them in separate piles. Start with one pile and charge it to its proper polarity and again pile separately or place on the flywheel in alternate sequence. Charge the other pile in the reverse direction; that is, simply turn the magnet over when charging, thus charging the magnet in the opposite direction; replace on the flywheel in the remaining spaces.

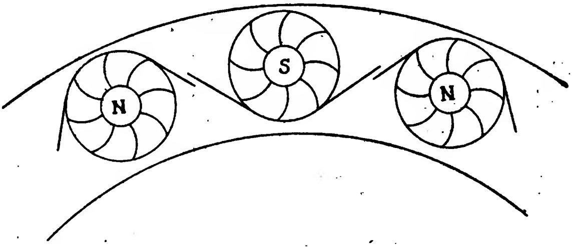


Fig. 413. Winding of Old-Style Coils

Repairing Magneto Coils. The coils on the spider after a time become grounded by fine particles of metal and carbon in the oil which work through the coil insulation and ground a portion of the magneto. Where a magneto fails to come up on charge, it is generally owing to this cause, and while washing out the crankcase rarely remedies the trouble, still it helps to prevent further trouble.

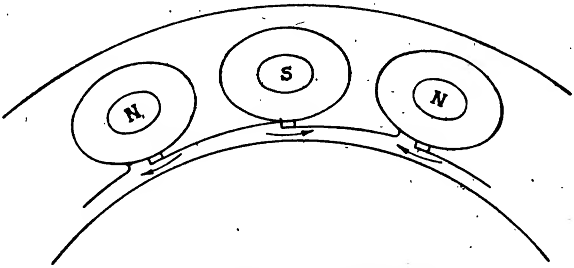


Fig. 414. Winding of New-Style Coils

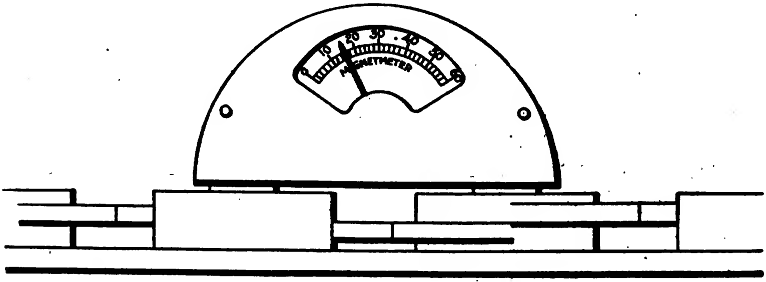


Fig. 415. Testing for Shorted Coils

The spider must be removed and the grounded portion reinsulated. The coils are tested by applying 110 volts with a lamp in series as in Fig. 412, first unsoldering the ground connection. If the lamp lights, a ground is present; slight grounds will cause a white smoke at the point of trouble but heavy grounds will not. By applying about 12 volts from a battery to the grounded coil, the ground will generally show up. If this fails, unsolder in the middle and test each half, when the ground may soon be found. The grounded coil should be forced off by using two screw drivers as levers. The old tape should be cut off and new tape put on, using cotton tape $\frac{3}{4}$ inch wide, wound with a lap of half the width of the tape; more than this will be too thick.

Where the fiber end pieces are broken, be sure to cut new ones from $\frac{1}{32}$-inch fiber. After tapeing, shellac well. In replacing the coils, connect each coil so that the polarity of adjoining coils will be opposite, the old style being shown in Fig. 413 and the new style in Fig. 414. After all the grounds are cleared and a final test is made, the ground connection may be replaced on the spider. A 6-volt battery current should now be applied to the whole assembly and each coil tested with a compass for polarity, thus proving that each pole is of opposite polarity to the poles on either side of it. This is very important.

To be sure that there are no shorted coils, the 6-volt current should be left on and each coil tested with the magnetmeter as in Fig. 415. The coil is now finished and should be given one more coat of shellac.

POLARIZATION OF HIGH-TENSION MAGNETOS

Missing of Sparks. For several years there has been doubt as to what causes a high-tension magneto to cut out or miss every other spark at high speeds and, in some extreme cases, at comparatively low speeds. This is true of several well-known and widely used makes, but the "miss" does not always take place under working conditions, as the type of engine may not permit of sufficiently high speed. In extreme cases it shows in speeding up in lower gears, such as in truck work without a governor. This trouble is usually laid to faulty workmanship in repairing the ignition or to the carburetion.

In mild cases—in about fifty per cent of the magnetos now in use—the missing shows up on the test stand and is very annoying to the tester as he may spend many hours trying to correct the fault. The natural tendency is to place the blame on the breaker or cams, as the miss occurs on one side only.

Causes. This action is caused by several conditions in both material and design. All high-tension armatures are made up of thin steel punchings, or laminations, built up in the center, with solid-iron end pieces, Fig. 416; these laminations and end pieces are riveted through the edges which hold the assembly together. This provides a laminated core, on which are wound the primary and secondary of the coil. All iron or steel has a reluctance to change its magnetic condition, that is, its state of charge or discharge; and the change which takes place from complete charge to complete discharge, or vice versa, takes a certain definite time, depending on the quality of the steel. The same trouble is encountered in transformer design, although it is overcome by using silicon-steel laminations, which have a very low time period of change. As the magneto armature rotates between pole pieces, Fig. 417, the magnetic lines of force are reversed once every half-revolution, therefore the magnetization of the laminations must rise and fall in strength likewise. This reversal takes place when the armature has cleared the pole piece about $\frac{1}{4}$ inch, position C,

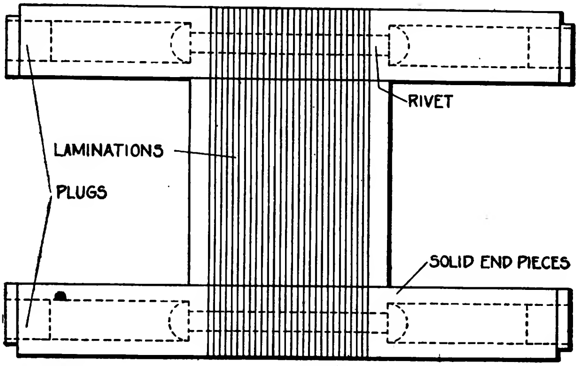


Fig. 416. Construction of Armature

Fig. 417; this is for full advance position, at which practically all running is done.

As the maximum spark is produced when the greatest magnetic change takes place, it naturally occurs at the full advanced position. The greater the current generated in the armature, the greater the saturation of the armature core and a relatively longer time period is then necessary for the rise and fall of the magnetization. At the full advance position, the points open about $\frac{1}{4}$ inch after the armature leaves the pole pieces; therefore the magnetic reversal must occur between the magnetic break and the electrical break. This provides the time interval necessary for the reversal of the magnetism in the iron. This polarization is due to three factors:

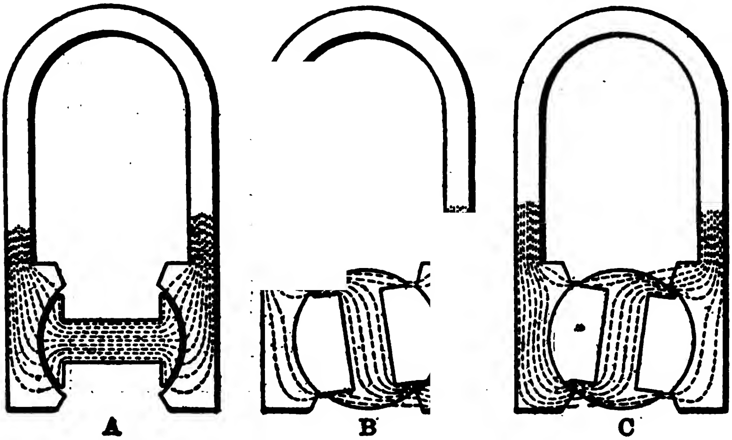


Fig. 417. Diagrams Showing Distribution of Magnetic Flux for Various Positions

Quality of iron used in the armature core
Speed of armature
Amount of current in the primary

Proofs. A magneto is placed in the test stand and the plug wires are connected to the multiple gap, Fig. 418. Starting with a low speed, each point will be seen to spark perfectly, and this will continue until a higher speed is reached, when two of the points, *1* and *4* or *2* and *3*, will cut out either all the time or intermittently. This failure closely resembles breaker trouble, but if the missing gap be shorted with a screw driver, the missing will be transferred

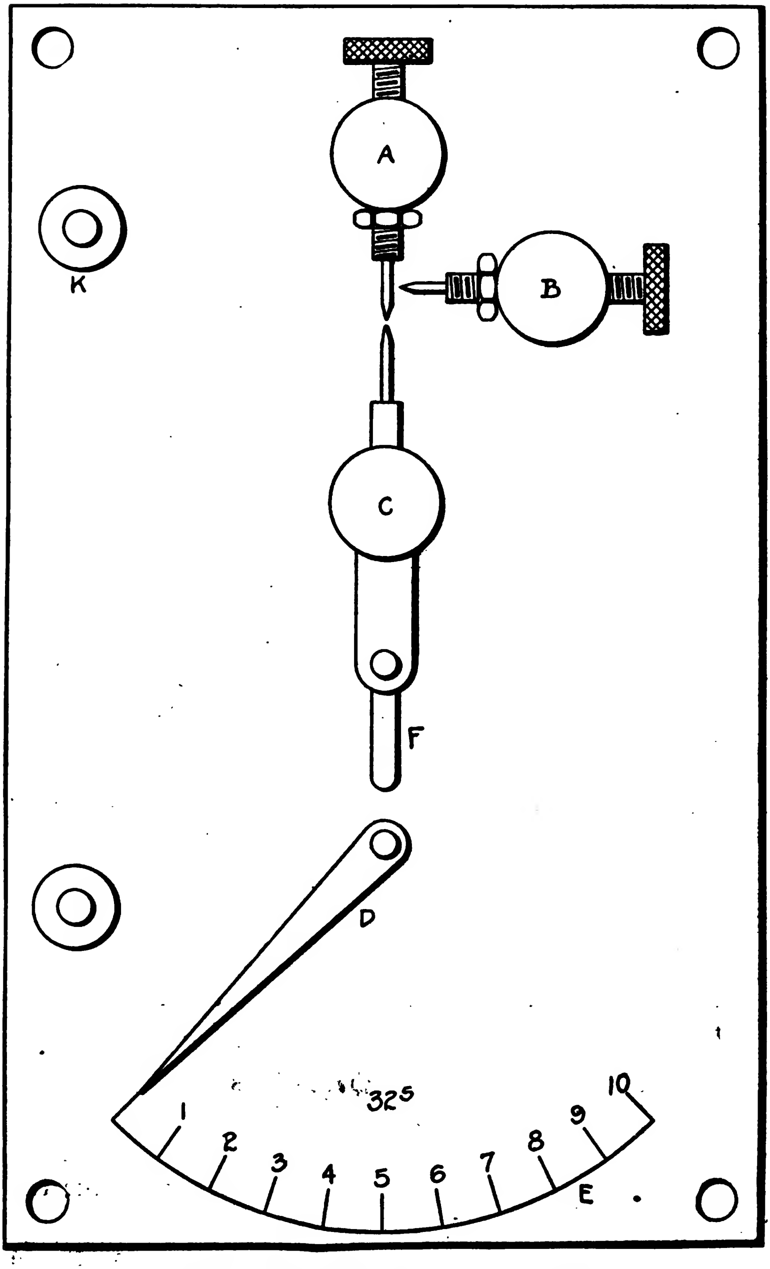


Fig. 418. High-Tension Test Points with Astatic Gap

to the opposite pair and may continue so, although in some cases it will return after a few sparks to the original pair.

Short-circuiting the failing gap offers less resistance to the secondary current, and a relatively greater amount of current is generated in the primary, which in turn polarizes the core in the opposite direction. The reversal may remain this way or the original polarization may be so strong that the first polarity will be restored. The fact that a greater armature current is one factor proves that the core does become polarized.

Some states of polarization are so slight that merely blowing on the gap will cool the arc and cause a reversal. If, when missing on one pair of gaps, the timing lever is slightly retarded, the missing will cease and all sparks will be equal. This shows that the time allowed between the magnetic break and the electrical break has been extended and that the iron has had time to reverse its magnetism.

Remedies. Manufacturers have found that this difficulty can be overcome by lengthening the magnetic break, but this gives an undesirable correspondingly smaller range of spark advance. The current generated in the primary during the time the points are closed affects this condition directly; reducing the current lessens the trouble with a certain reduction in the quality of the spark.

The use of proper iron in the core is the real remedy—the main factor in the design—and high-grade silicon transformer steel would practically eliminate this trouble in new armatures. Iron, after constant use involving continual reversals, becomes fatigued and sluggish to reversal, which accounts for armatures developing this trouble after several years' service.

TESTING AND CHARGING

HIGH-TENSION COIL AND ARMATURE TESTING

Methods. There are two methods of testing high-tension coil and armatures: first, with a master vibrator; second, with a single-break interrupter. In either case a spark gap of constant distance and resistance should be placed in the secondary circuit; this is done with the astatic gap.

Astatic Gap. The astatic gap has three points, Fig. 418. Point *A* is connected to the high-tension lead of the coil or armature, while the point *B* is insulated and is the static point. The function of the static point is to maintain an even resistance between the points *A* and *C*, thereby giving a definite resistance for a given distance; this is of prime importance to provide a reliable test.

The action of the static point is to produce a capacity at the points in tune with the oscillations of the high-tension discharge. As the secondary current from any high-tension coil is of high frequency, although greatly damped because of the amount of iron in the coil or armature, the introduction of a capacity or condenser action into the circuit has a direct bearing on the gap.

The distance between the points *A* and *B* should be 0.002 inch. The two terminal posts should be connected on the back of the fiber base by a small wire. The body of the posts *A*, *B*, *C* should be ⅝ inch in diameter, especially the static point; too small a mass will not furnish sufficient capacity to work properly. Phonograph points are good for this purpose and are easily mounted. Lock nuts should be used on screws *A* and *B* and also on *C* if necessary.

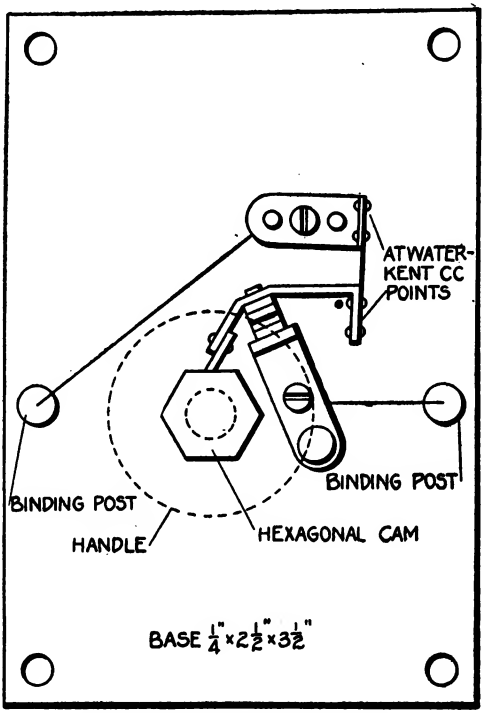


Fig. 419. Breaker-Point Test Set

Testing with Vibrator. A master vibrator is placed in series with a 6-volt storage battery and the coil to be tested, the high-tension lead being connected to the terminals on *A* and *C* and grounded to the primary of the coil. With the spark jumping the gap, the point *C* is opened until the spark will just jump it continuously. If the gap measurement is taken with a good coil a standard is obtained.

After the vibrator is once set it should not be changed; any change in adjustment will mean a change in the quality of the spark. As some high-tension armatures have such a high primary resistance that a vibrator will not operate through them, a single-break interrupter may be used to overcome this difficulty.

Single-Break Test. A simple cheap breaker may be made as in Fig. 419. A piece of ¼-inch red fibre 2½″×3½″ forms the base; Atwater-Kent type CC points are used for contacts; the hexagon cam is made from a ⅜-inch hexagon iron rod turned down to a shoulder ¼ inch in diameter and projects through the base, with a fiber handle about an inch in diameter attached. A condenser is connected across the points, and the whole assembly mounted on the test board. To test with this apparatus, the coil is connected as in Fig. 420; the battery coil primary and breaker are connected in series; the coil secondary is connected to the gap, and the spark is noted. As this type of breaker has no resistance to speak of and is operated by hand, the coil has plenty of time to saturate its core, the spark produced being uniform.

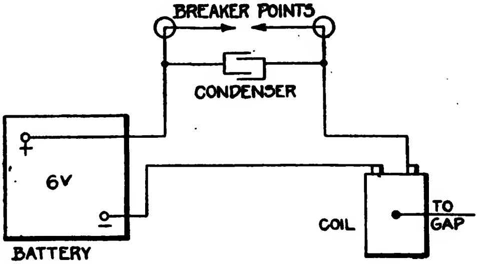


Fig. 420. Method of Connecting for Test

Special Dial Gap. For quick results, utilize the special dial gap, Fig. 418. This gap has a fiber base ¼″×3¼″×5½″, on which are mounted two stationary points marked *A* and *B* and a grounded movable point *C;* below is a pointer *D*, which moves on the scale *E*. The movable point *C* slides in the slot *F* and is held by a plate and two rivets. The lower part of the point body *C* projects through and forms one rivet, while the other projects through the plate about ¼ inch, and the cam bears on it, as well as the spring, holding the plate assembly against the cam. Point *A* is connected on the back to terminal *K*.

The dial *E* is cut in the fiber and white lead put in the cuts. This dial is laid out in ten divisions, marked 1, 2, 3, 4, etc., and moving the pointer one division causes the gap to change 1/32 inch. In using this apparatus, the dial makes it possible to get a quick positive reading. A table can be made up to show just what each type of armature or coil should test, thus eliminating all guesswork.

MAGNET TESTING AND CHARGING

Magnet Materials. The permanent magnets used in magnetos are generally made of tungsten or chrome steel. Tungsten magnets were in extensive use until the cost of this metal became so great during the War that it was necessary to develop a less expensive material. A few prominent manufacturers are having excellent results with properly treated chrome steel, and as it is less expensive, it is considered the ideal magnet material.

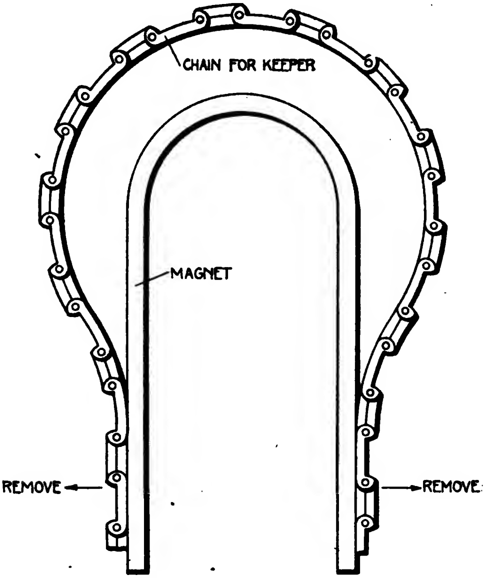


Fig. 421. Flexible Magnet Keeper

Keeper. A keeper must be used when the magnet is removed from the magneto or when the armature is removed from the field. A careful test has shown that a magnet will lose about thirty per cent of its strength if a keeper is not used while removing the magnet from the charger to its proper position on the magneto, or vice versa; the magnet was again removed and replaced without a keeper, with an additional loss of two or three per cent. The magnet was then allowed to stand on a shelf for three or four days without a keeper; on testing it was found to have lost an additional five or ten per cent. The same magnet was charged, a keeper being installed before removing the magnet from the charger, and it was then tested for strength. After the magnet had stood for six months, a test showed the strength to be the same as on the first day.

From the foregoing it will be noted that thirty per cent—the greatest amount of lost strength—was lost at the instant the magnet was removed, either from the charger or from the magneto without a keeper. There are a number of testers on the market, but several of them are of little use as the first loss occurs before the tester can be placed in operation. The aforementioned test was made by measuring the voltage between the brushes of a direct-current constant-speed generator, the magnets to be tested forming the field of the generator. Any loss in magnet strength would cause a lower voltage reading.

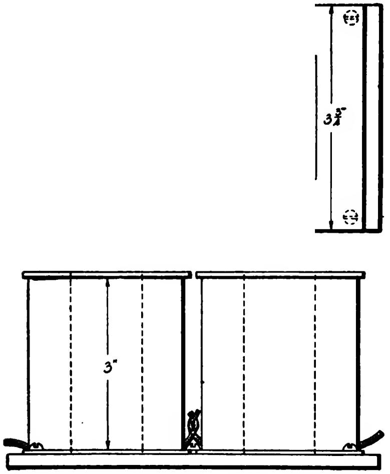


Fig. 422. Construction of Magnet Recharger

A prominent manufacturer recommends that a keeper be constructed from an old silent chain. After annealing, the chain is put over the magnet, Fig. 421, in such a way that the magnet can be placed in position before it is necessary to remove the keeper.

Testing. There are several ways of testing a magnet, such as with a compass, by the scale method, or by a voltage test as above described. When a compass is used, it is placed on a table with the needle at rest and pointing north; the magnet to be tested is placed in a line at right angles to the needle and about 3 feet from it and the deflection noted. This method is inaccurate as the deflection does not vary much from weak to strong, and it takes too much time.

The scale method is not entirely satisfactory as there is a loss during the test. The magnet has a keeper; this keeper is pulled away until it leaves the magnet and the pull in pounds noted.

Charger. In charging a magnet it is necessary to saturate it in order that it will retain the maximum charge. This can best be done with a charger having a heavy field and a short magnetic circuit with sufficient cross-section of iron to keep down the reluctance. It has been found by experience that to obtain the strongest magnet, there must be a short magnetic circuit. Therefore, if the magnet projects into the coils as in a solenoid, the magnetic circuit has been reduced to the length of the magnet plus the keeper on the bottom. If we have, in addition, a core in each coil 3 inches long, 6 inches of length have been added to the magnetic circuit, and the result is poor saturation.

A satisfactory magnet charger can be obtained at a low price in any voltage from 6 to 220 or one may be made as follows:

Two brass spools are made, Fig. 422, with a hollow center 1″×1¾″×3″, to which are soldered the end pieces. To operate on 6 volts, these spools are wound full of No. 14 magnet wire, with the coils wound in opposite directions, Fig. 423, and the two coils connected in multiple. If 110 volts is used, wind with No. 22 wire and connect in series.

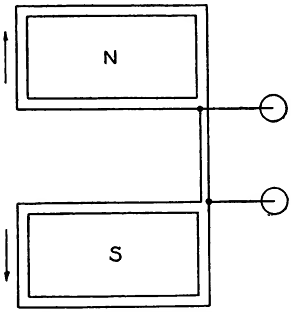


Fig. 423. Wiring Magnet Charger

Charging. In charging, the magnet is held above and at right angles to the charger and the current applied for a second, when the magnet will swing to the position it should occupy in the charger to receive a proper charge. Place the magnet in the coils, apply current for one second and the magnet is charged; any longer application is a waste of current and time.

If a keeper be placed on a magnet and pulled toward the top of the magnet, most of the magnetism will vanish because of the distortion of the magnetic lines of the circuit.

IGNITION SYSTEMS

BATTERY SYSTEMS

Atwater-Kent. In setting the points of this type of ignition system, it is necessary that the lifter throw the points far enough together so that a long contact is made and a subsequent saturation of the coil takes place. This may be determined by holding the lifter and slowly turning the engine over. When the lifter snaps off the notched shaft, allow it to return slowly and note how far the

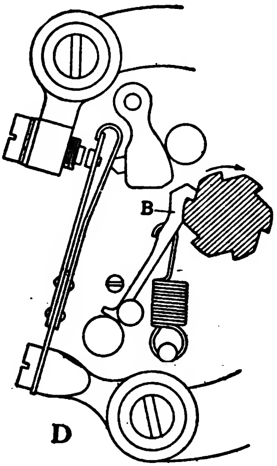


Fig. 424. Diagram Showing Operation of Atwater-Kent Interrupter

points are compressed, as at *C*, Fig. 424. If the points do not move far enough, the cause may be wear on the lifter, on the notched shaft, or on the anvil, or the anvil post may be bent. Examine these parts for wear and if they are worn, replace them.

Temporary relief may be had by bending the anvil post *D* toward the notched shaft, thus giving more movement. As wear of moving parts comes from lack of oil, be sure to oil all the moving parts every 1000 miles.

In adjusting see that the lifter *B* clears the edge of the anvil *D* about 0.005 inch on its forward movement, no more and no less, if less, the lifter is likely to strike and break. Continual breaking of lifters is usually due to their striking on the way forward or from a worn roller cushion; the break generally happens at high speed, as on an eight-cylinder engine. This roller is struck by the lifter; and there will be difficulties ahead if the roller is worn too much or is solid on the pin; the jar is then sufficient to break the lifter at high speed when the blows follow one another very closely.

The spring carrying the contact point should bear against the anvil sufficiently to give a uniform break or the contacts may stick. Four- and six-cylinder lifters are alike, while the eight-cylinder has an angle as shown, Fig. 425. If a four-cylinder lifter is used in an eight-cylinder head, there will be insufficient contact and the shoulder of the lifter will strike the notched shaft too soon.

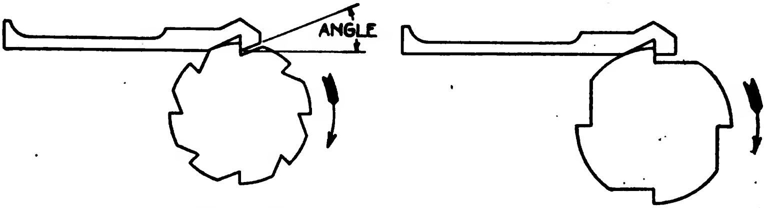


Fig. 425. Angle of Four- and Eight-Cylinder Lifters

When contact points become yellow, it is a sign that the condenser is weak. In the H or K–2 system the condenser is in the coil box and can be renewed by taking off the base, digging out the wax on the narrow side of the partition, and then installing a new condenser.

The condenser on the K–3 is on the head, the case being held on by two screws. The condenser has two leads, one of which is grounded while the other touches the condenser case. This case should have a steel spring holding the condenser in place, otherwise vibration will break the leads.

Atwater-Kent Closed-Circuit Type. The new type CC operates on the closed-circuit principle and is free from some of the troubles of the open-circuit system. The points are opened by a steel cam, the movable point having no pivoted hinge to wear but moving on a steel spring. Bearing on the cam is a small fiber block, and as the pressure on the cam is slight, the wear is negligible. The assembly is held by one screw, two dowels punched on the bracket ensuring a positive adjustment. The large tungsten points should separate 0.006 inch, the adjustment being made from the stationary point fastened to the condenser case, Fig. 426. The circuit is shown in Fig. 427.

Fig. 426. Atwater-Kent Closed Circuit Breaker

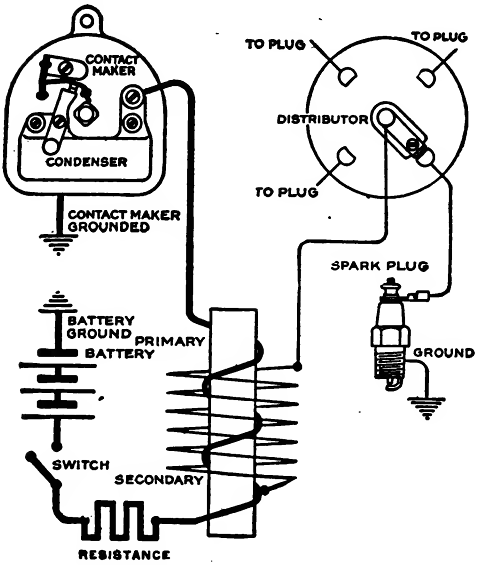


Fig. 427. Wiring of Atwater-Kent Closed Circuit System

The coil is of simple construction and has a ballast coil in the top cap. This heats at slow engine speed or when the engine is stopped with the switch left on and prevents the points from burning or the coil from burning out. A single-pole switch is used.

Atwater-Kent Automatic Type. The type CA has a governor for advancing the spark and can be used with or without a manual control. Where a manual control is used, the unisparker shank is marked **REST** or **RESTRICTED**, while the straight automatic is marked **FULL.**

In replacing a K–2 or K–3 with a CA, the timing is the same except that the spark must be slightly retarded as the CA type has no lag.

Connecticut Automatic Switch. The new Connecticut system differs from the older types in that the head is more compact and the advance lever is connected to a separate plate, on which are mounted the points, while the body of the head remains stationary. The point plate is shown removed in Fig. 428. To replace the points, a new plate assembly is used since the breaker arm is riveted to this plate, as shown in the illustration.

The automatic switch used with this head, Fig. 429, operates as follows: the current enters at post *B* and goes to insulated spring *a* (which makes contact with spring *b*) when the insulated plunger *c* is pressed in and held in position by the latch *d*. Current is conducted through the wire *e*, the bar of thermostatic metal *f*, back through the heater tape *g* to post *c* and thence to the coil. If an uninterrupted flow of current is allowed to pass through the heater tape *g*, the thermostatic bar *f* will bend down and make contact on the post *h*, setting up a vibrator action between the coil *i*, hammer *j*, and ground post *G*. This will actuate the hammer *j* and, striking the latch *d*, will dislodge it, allowing the plunger *c* to return to the off position, thus breaking the circuit between the springs *a* and *b*. Pressing the plunger *k* by hand will also dislodge the latch *d* and accomplish the same result

Fig. 428. Removing Breaker-Point Plate

Fig. 429. Connecticut Automatic Switch

In some cases this switch will throw off too soon and stop the motor while it is running slowly. To overcome this, bend the post *h* slightly away from the thermostatic arm *f*, adjusting it so that the vibrator will operate one minute after the switch is closed with the motor stopped; this will give the right setting. The chief trouble with this switch is the burning away of the heater tape *g*, opening the circuit. When this happens, a complete new vibrator unit should be installed, the entire assembly costing very little.

As the 1919 model automatic switch has no vibrator, a double thermostat is used; it is simpler and less likely to get out of order. Fig. 430 shows the arrangement of the two units. The current enters at *B* and flows to the insulated spring *a*, which makes contact with thermostatic bar *b*. When the insulated plunger *c* is pressed in and held in position by the thermostatic latch *d*, current is conducted through the heater tape *e* to the post *C*, thence to the coil. If an uninterrupted current is allowed to flow through the heater tape *e*, the thermostatic bar *b* will bend down and make contact on the adjustment screw *f*, allowing the current to flow through the heater tape *g* to the ground post *G*, thus bending up the thermostatic latch *d* sufficiently to release the plunger *c*. Manually pulling out the plunger *c* will release the latch and accomplish the same result.

Fig. 430. Connecticut Thermostatic Switch

In setting the thermostat to act in the proper interval, the adjustment *f* is turned in to increase the time and out to reduce it. It will be noted that the thermostatic bar *b* has a coarse winding and is in series with the coil, while the thermostatic latch *d* has a fine winding and is connected across the battery only when the series bar is in contact to cut off the ignition.

The coil is encased in a one-piece composition housing, closed at the base with a sealed metal cover. Running along the side of the coil is a brass ground strip. In the coil base is the condenser connected across the two flexible leads that connect to the breaker points. In time, or if it gets wet, this condenser weakens. To replace the condenser, remove the base cap and take out the old condenser. Use a new one if available; two thick Splitdorf TS condensers are satisfactory if connected in multiple.

North-East Ignition. The North-East ignition head as used on the Dodge car is a self-contained unit having the distributor, breaker, coil, and governor all in one assembly. The breaker, Fig. 431, has a lever on which is mounted a tungsten contact point which makes contact with a similar point mounted on an adjustable screw. On this lever is a fiber block which bears on the steel cam; this lever and the adjustable point are insulated from the ground. The timing is changed by unscrewing the lock nut in the center of the cam and rotating the cam to the desired timing; the spark occurs at the instant the points separate. The condenser is mounted in the semicircular metal case next to the points and is connected across the contact points. When a condenser becomes weak or is short-circuited, it is necessary to install a new one. If the engine stalls owing to a short-circuited condenser, the motor can be started by disconnecting one lead and will run without the condenser; the motor will not operate satisfactorily, but will run well enough to save towing the car to a repair shop.

Fig. 431. North-East Ignition Breaker

If there is a loose point on the breaker lever, reriveting the point will overcome the trouble, but in making the repair do not pound too hard on the tungsten or it will crack. The points should be set to open about 0.015 inch; if set wider, the period of contact is so short that missing is likely to occur at high speed. The complete head assembly is shown in Fig. 432. The vertical camshaft carries a gear at its lower end which meshes with the governor gear. The automatic advance governor, which is mounted on the horizontal shaft and rotates at engine speed, consists of two weights hinged on a stationary disc attached to the shaft. As the weights move outward, owing to the centrifugal force, they move the governor gear about 25 degrees on the horizontal shaft, thereby advancing the spark. The head is also equipped with a manual advance; the automatic takes care of a portion of the advance.

The coil is enclosed in an iron case with the head and has a closed magnetic circuit; it is impregnated with varnish to render it waterproof; and it is held in place by a stud running through the core. A water-tight cap covers the case, and a high-tension post makes contact with the coil secondary, this coil operating on 12 volts and requiring a small amount of current. As this current is so slight, no ballast is used on the system and a quick saturation is obtained with no burning at the points. The fact that it will work after a fashion without a condenser is due to the small amount of current. Very light grease is packed into the governor case; a wick oils the vertical shaft; and a grease cup oils the horizontal shaft. When replacing this unit with a magneto, the

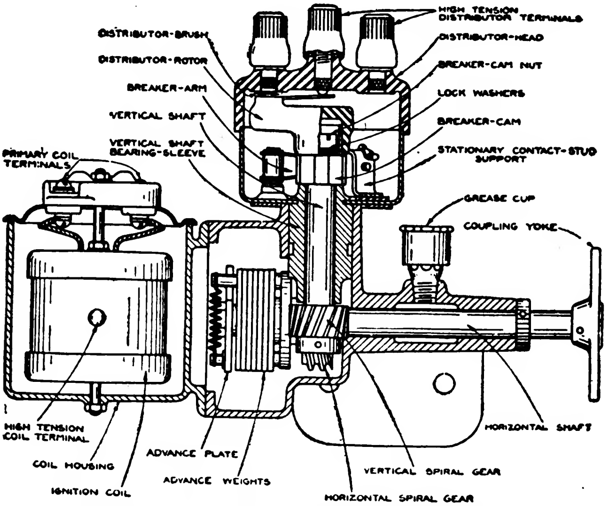


Fig. 432. Cross-Section of North-East Ignition Unit

entire head is taken off and a magneto base installed. Any standard base magneto will fit without machining.

Westinghouse Horizontal Ignition. This unit is mounted on the front of the generator and has an automatic advance which may be used for full advance or for restricted ignition. The governor weights are mounted on two studs screwed into the armature shaft and are insulated from them by fiber bushings in the weights, which also form the cam for operating the breaker points; they are so shaped as to hold the points together as they expand, thereby making a longer period of contact as well as opening the points sooner and so advancing the spark. The weights are normally held in a retarded position by the spring on the end of the shaft which bears on the fiber bushings. Fig. 433 shows the weights in the position of full advance.

Fig. 433. Westinghouse Horizontal Breaker

The points are platinum and should normally remain open 0.008 inch. Tungsten points last longer and are cheaper. In adjusting the breaker, the contact spring, Fig. 433, should bear lightly on the contact screw with the breaker lever depressed. This contact spring, however, must not be too strong, as it works against the pressure of the bumper spring and if they equalize each other, the lever will not return to the stop and the spark will be irregular. The condenser is located in a pocket case in the end plate and is enclosed in sealing wax. In time the condenser will become weak —generally from dampness—and should be replaced by a new type molded in hard damp-proof rubber. When installing the new condenser, be sure to fill the pocket spaces with sealing wax; this will make the condenser rigid.

The distributor contains the high-tension coil, having a primary of flat copper ribbon which is wound on edge around a laminated iron core and over which are placed the two secondary bobbins connected in series. Should the primary coil burn out, it may be rewound with 250 turns of No. 22 enameled magnet wire, which is equivalent to its original winding.

The switch is on the dash and contains a reversing device in the form of a square plug which reverses the direction of the current through the points and causes them to burn evenly. The switch also contains a ballast coil, which for a 6-volt system should be of 0.45 ohm and for a 12-volt of 1.2 ohms resistance; the 0.45-ohm coil is painted red, while the 1.2-ohm coil is not painted. This ballast coil heats as the engine slows down or is stopped with the switch on, raising the resistance of the ballast coil and preventing the ignition coil from being burned out. A diagram of this system is shown in Fig. 434. In testing the high-tension coil for strength, the spark should jump $\frac{5}{16}$ inch on the astatic gap with a 0.45-ohm ballast coil in series with the primary. Be sure to use a ballast coil in testing—without it, the reading will be incorrect.

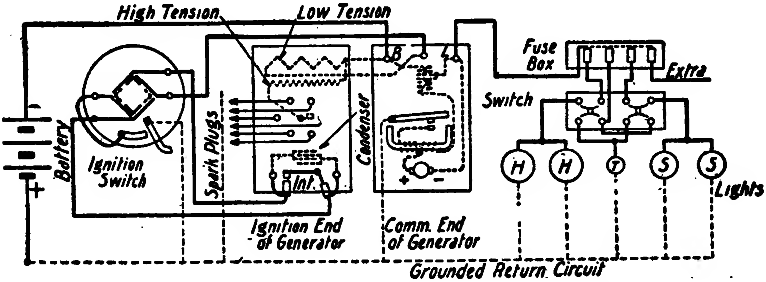


Fig. 434. Wiring Diagram of Westinghouse Horizontal Breaker

Westinghouse Vertical Ignition. In removing the ignition unit for repairs, disconnect the three wires; it is not necessary to mark them. Retard the spark fully and make a light scratch on each side of the rotor in this position, thus making the replacement easy. In replacing, turn the rotor to the marks on the collector ring and slip the gears into mesh. Then turn the ignition switch on and hold the three wire terminals near the frame, connecting to either outside terminal post the one that sparks to the frame. Turn the switch a half-turn to the other on position and try the other wires. Next place the live wire on the other outside post and the remaining wire on the center post. When either of these wires shows a heavy discharge to the ground instead of about 8 amperes, it will be known that the switch is not connected properly; this applies to a single-wire system, Fig. 435. If the connections are wrong, the coils may burn out.

When all connections are made properly and the motor is ready to run, the ammeter should show a 5- or 6-ampere discharge with the contacts together. When installing a new condenser, be sure that the leads are in good condition as they are very close to the coil laminations and are likely to be grounded on them. A frequent cause of missing under a load is the reversal of the distributor rotor and the subsequent shortening of the safety spark gap, thus lowering the circuit's resistance and causing a jump at the safety gap instead of in the cylinder. When in good condition the coil should jump ⅜ inch on the astatic tester with a 0.45-ohm ballast coil in series with the primary.

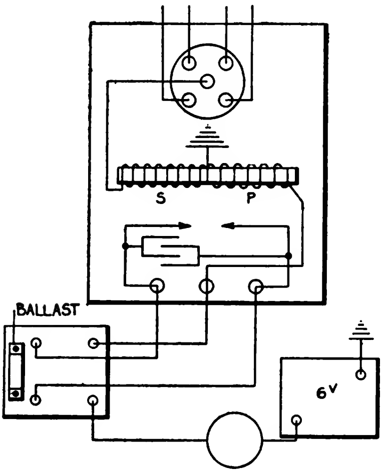


Fig. 435. Westinghouse Ignition Wiring

MAGNETO SYSTEMS

Eisemann Dual Magneto. Dual magnetos are used on large trucks and some touring cars. The Eisemann type is waterproof and very compact. The pole pieces, also an Eisemann feature, are tapered, Fig. 436. This gives a projection in the center which is used to shorten the magnetic break of the armature at the retarded position and produces a uniform spark throughout its range of advance. The breaker mechanism is shown in Fig. 437. The breaker arm rotates on a fiber bushing, insulating it from the breaker disc. The battery breaker is mounted on the timing lever and is actuated by a steel cam carried on the magneto breaker; the battery breaker is set to open 10 degrees later than the magneto breaker.

Fig. 436. Eisemann Pole Pieces

The coil circuit is shown in Fig. 438. In front of the coil is a breaker mechanism for starting on the spark, Fig. 439. The fiber ratchet bears on the fiber roller *A*, which is mounted on the lever *B*. On the end of this lever are two points *C*, one on each side. Normally the lever points rest on the stationary point, which is connected to the battery breaker, and therefore these points are in series with the battery-breaker system. Opposite this point is another point, *D*, mounted on a movable grounded plunger. The action of rotating the ratchet causes the lever *B* to move from the stationary point and, if the battery-breaker points are together, to interrupt the circuit and cause a spark in the cylinder. If the points are not in contact, the lever *B*, touching the plunger *C*,

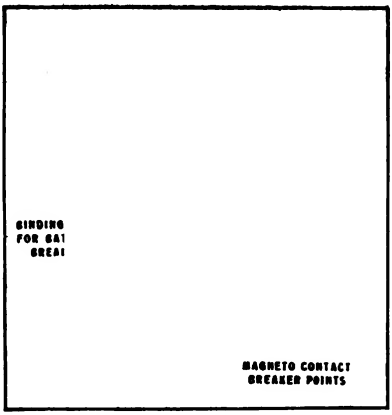


Fig. 437. Eisemann Breaker Mechanism

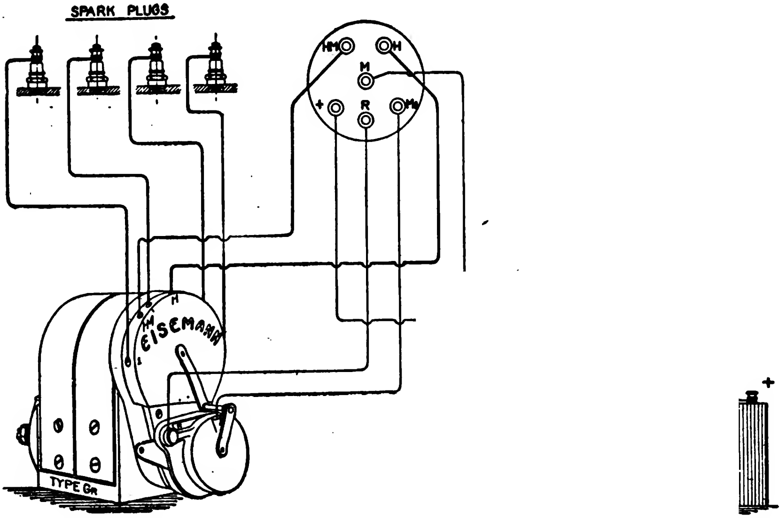


Fig. 438. Wiring Diagram of Eisemann Dual Magneto

closes the circuit and, as *B* is in multiple with the breaker points, a spark results.

Some coils have the roller *A* of brass and others of fiber; the ratchet is also of either fiber or brass. Should a brass ratchet be used with a brass roller, the lever *B* will be grounded and the system will not operate. Should the fiber roller *A* break while a brass ratchet is employed, a ground will result. If the coil ground wire *M* becomes loose or broken, the battery-system current is shunted through the magneto breaker, annealing the interrupter

Fig. 439. Eisemann Coil Breaker

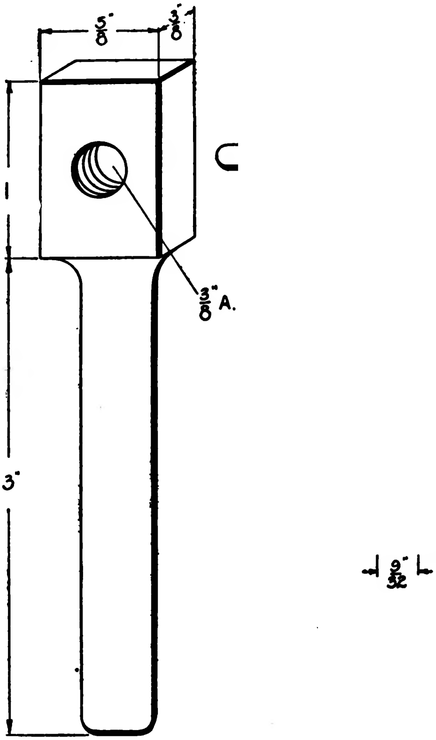


Fig. 440. Special Governor Puller for Eisemann

spring and putting the magneto out of commission. A reversal of the wires *R* and *Ma* has practically the same result. Dirty ground brushes in the magneto will cause the magneto to fail to shut off and will also burn and pit the distributor gear and bearing. In testing the coil winding, the spark should jump $\frac{3}{8}$ inch on the astatic gap test.

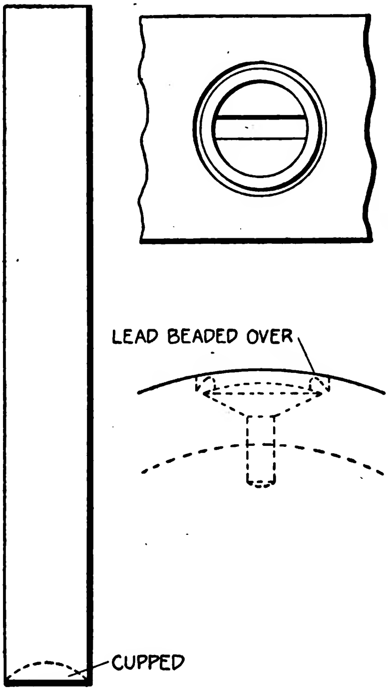


Fig. 441. Double Lock Punch

Eisemann Automatic Governor. This new automatic governor has a latch to prevent knocking at low speeds. This latch disengages when the speed reaches a point where centrifugal force throws the latch free and the governor opens; once open it does not close until a very low speed is reached. In removing the governor from the armature shaft, a special puller is used, Fig. 440. The small end of this puller screw should be hardened to prevent spreading. In replacing the governor, a press should be used, taking care that the armature end plate is not bent from the pressure.

A four-cylinder governor advances the spark 38 degrees while a six advances 57 degrees, this increased advance on a six being due to the fact that a six-cylinder magneto operates at $1\frac{1}{2}$ times engine speed. With this arrangement the same advance may be obtained with a six as with a four. The old-style Franklin governor uses lead subweights which are held on by four screws; these screws work out unless properly locked. A lock punch is shown in Fig. 441 as well as the bead turned by it. In assembling, be

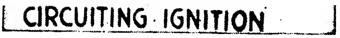


Fig. 442. Eisemann G-4

sure to place the governor in the case first, as the lead weights will not pass by the case opening.

Fig. 443. Breaker Points, Single-Lock

Eisemann G-4 1st Edition Magneto. This is the weatherproof type Eisemann. The armature differs slightly from the general practice, having the collector ring on the breaker end instead of the drive end, while the condenser is on the drive end. Two sharp screws in line with the sharp edge of the collector ring and projecting from the gear housing act as the safety spark gap. The breaker, Fig. 442, has a different type of breaker arm, consisting of a flat spring which carries a platinum point re-enforced by a pressure spring. The points are opened by striking the fiber cams on the timing lever. A brush is held in the breaker retaining screw and bears on the breaker cap and is connected to the switch for stopping the engine.

The distributor disc has an R and L timing mark which lines up with the index screw on the gear housing used for timing the magneto to the engine. A fixed advance magneto should have a distributor disc marked with an F, while the variable has a V. Unless this setting is correct, the timing marks are useless. The distributor bearing is eccentric for gear-meshing adjustment and is held in by screws and lock washers. If short-circuited, the condenser may be "burned out" by placing it directly across a 110-volt line, when the short will burn off, making the condenser as good as new. The spark should test up to $\frac{7}{16}$ inch on the test gap. When assembling, lock the screws as in Fig. 443, as a tongue of metal formed in the screw slot in the

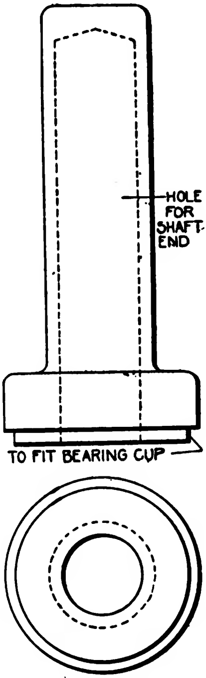


Fig. 444. Bearing Cup Drift

old way will not hold. When bearings loosen in the end plates, they should be reinsulated. A fish-paper gasket and strip are used, 0.012 inch thick, and the bearing cup driven in with a cup drift, Fig. 444. This lower offset should exactly fit a 15-millimeter ball cup, being flush with the outside of the cup.

The points originally used were of platinum and should be set $\frac{1}{64}$ inch apart on the break. A special wrench is furnished to adjust the points through the slot in the lower side of the timing lever. The two breaks should be exactly alike, and in case one is wider, the cam causing the wide gap should be filed down so that both are even. Do not attempt to put in new fiber cam blocks as they are put in by machine; those put in by hand will work loose. As considerable trouble was encountered with platinum points, the factory supplied special points termed *Crecium* points. This is a hard substance similar to tungsten; it lasts longer and gives less trouble. To install Crecium points, the contact bracket is cut away and the lug next to the point is removed to allow for the head of the Crecium screw. This screw is shaped differently to distinguish it from a platinum screw. The point spring should have sufficient pressure against the adjustable point to bear firmly without the aid of the pressure spring. To test, pull away the pressure spring and note whether the point spring remains on contact. A poor spring tension will cause missing at high speed due to the spring not returning to contact in time for the next spark. When the timing lever becomes loose on the triangle plate, a new lever should be installed.

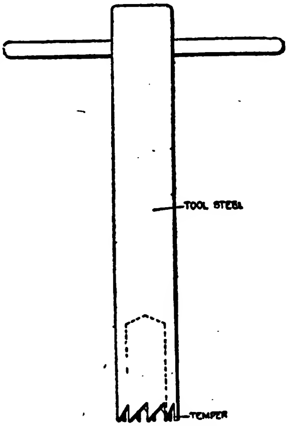


Fig. 445. Bushing Reamer

Eisemann G–4—2d Edition. This edition and model is an improvement over the first edition in that the pole pieces, end plates, and gear housing are cast in one piece. The triangular plate at the end of the magneto is held in place by two studs and one screw. The bearings at the drive end of this magneto are insulated from the housing. When it becomes necessary to reinsulate this bearing, the cup should be driven in with a drift and the edges of the insulation trimmed with a knife or screw driver. The breaker of this edition differs from that of the old style, or first edition, as it consists of a pivoted breaker arm, Fig. 437. The breaker-arm bearing is made of a special material which wears very little. This bearing is self-lubricating, as there are fine threads of fabric in the bearing which retain the oil and distribute it in the desired amount. These bushings sometimes swell, causing the bearing to grind and the breaker arm to stick in the open position, thus causing total ignition failure. When this occurs, the bushings should be fitted by using the reamer, Fig. 445. This reamer should be made of tool steel tempered to a deep blue. The center hole should be drilled and bored very accurately to the size of the rocker-arm pinion and should be very smooth.

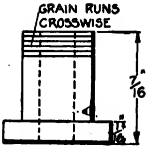


Fig. 446. Breaker Bushing

The teeth of cutters should be straight cut; no adjustment is needed, as the arms are all uniform. When bushings are worn, new ones can be made from white fiber, Fig. 446, the center hole being drilled and the fiber placed on a mandrel and turned down to size. When installing on the breaker, drive the bushings on, ream to size and to proper height, and then cut the top level with the center post. Platinum points are used and the arm point is riveted on. In some cases it becomes loose. In tightening or when installing new points, plain riveting will not hold, but the point should be beaded over, Fig. 447, using a punch as shown. The punch is made of tool steel and tempered to a deep blue. When riveting, the point should project into a steel

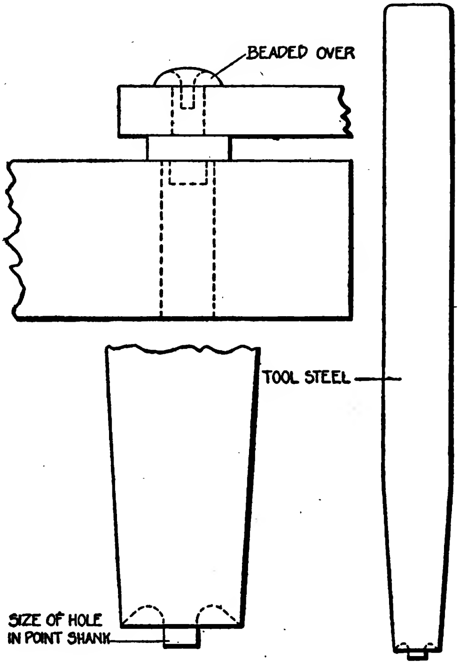


Fig. 447. Mounting a Breaker Point

plate with a hole a trifle larger than the point, allowing the steel shank of the point to take the force of the blow, as the platinum will hammer out of shape if placed on a flat surface.

The first 2d edition magnetos put on the market had cast-iron breaker arms which broke from the constant jar and were replaced with an arm made of Tobin bronze. Crecium or tungsten points cannot be used with this type of breaker, as the pounding of the points cracks and pulverizes the hard metal. The points should open $\frac{1}{64}$ inch.

Eisemann Impulse Starter. Large engines equipped with magnetos, such as used on trucks and tractors, are difficult to start, especially when cold. An impulse starter is accordingly provided to give a maximum spark at slow cranking speeds. The impulse starter takes the place of the coupling and is about the same length and is easy to install. Fig. 448 shows its internal mechanism to consist of but five essential members: a housing *H*, attached to the magneto shaft; a driving member *C*, which is itself driven by the engine; a spiral spring *S*, hooked to members *H* and *C;* a floating member, or trigger, *T;* and a fixed bar *B*, which is mounted on the base of the magneto. Its operation is as follows:

Fig. 448. Impulse Starter on Eisemann Magneto

Position *A*—when the motor is slowly cranked, the trigger *T* drops by gravity, engages with the bar *B*, and thus temporarily prevents the rotation of the housing *H*. As the cranking continues to turn the member *C*, the spring *S* is compressed until the cam at *C* strikes the wedge *W*. This forces the trigger upward until it slips off the lower bar, thus releasing the housing *H* and allowing the heavy pressure stored in the spiral spring to give the armature a very sharp twist forward. This action causes the magneto to produce a powerful spark which should start the motor.

Position *B*—this shows the condition after the release and in the normal running position. It will be seen that stops are provided on the housing and on the outer part of the member *C* for preventing the armature from being thrown past the normal position. It will also be noted that the member *T* is heavily overweighted on its upper half. The action of centrifugal force on this counterweight draws the member still farther until a tooth on the latter enters a notch *N* in the driving member *C* and holds it there as long as the motor continues to operate. This notch thus gives a positive drive for the magneto.

Fig. 449. Bosch Dual Breaker Box

These impulse starters are made for both R and L rotation, but should one need to be reversed, a driving flange *C* only is needed to make the change. In case the starter becomes broken, a small locking device is provided to prevent the trigger *T* from engaging the stop *B*.

Bosch DU Dual Magneto. The Bosch dual magneto has a separate breaker and high-tension coil but uses the magneto distributor. The breaker, Fig. 449, is mounted on the timing lever and is actuated by a cam on the magneto-breaker disc. This cam is steel and is set to open the battery breaker 10 degrees later than the magneto breaker, thus making it possible to set the magneto breaker 10 degrees ahead of dead center. This is desirable with six-cylinder engines, as the six-cylinder magneto rotates at one and one-half engine speed, which reduces its actual advance by one-third. On some models this cam is adjustable. The breaker points should open 0.015 inch.

The coil mounted on the dash has a vibrator for starting, Fig. 450, which is connected into the circuit by pressing the button on the coil or by turning the button to the starting position. In setting this vibrator, first see that the points are clean. This can be done by taking off the small cross plate which carries the button and noting how the spring assembly is placed. In adjusting the points, loosen the small screw that holds the button and turn the platinum point screw up or down, using a wrench as in Fig. 451. Turn the button to the start side and be sure that a good spark is obtained.

Fig. 450. End of Dash Coil

The four contacts at the left of the vibrator, Fig. 450, soon become dirty and cause a poor contact on the battery-breaker line as the lower contacts are in series with the breaker. This is indicated by a continual vibration on the start side and a stoppage of the engine when turned to **Run.** It is also likely to kick back as the spark delivered to the cylinder is continuous. To clean these points, remove the double contact plate and clean it with a platinum file, taking care not to break the wire attached.

In some cases a poor ground brush connection in the magneto, due to dirt or a loose ground wire on the coil, will cause the magneto to fail to shut off when the switch is thrown to the off position. This will result in the high-tension spark passing from No. 3 terminal contact to the switch contact and then jumping the intervening space to terminal contact No. 4, Fig. 450. This results in the burning of the hard-rubber terminal block and puts the magneto out of commission. When the magneto fails to stop on the off position, place the switch on the magneto side and kill the engine. This will save the coil. Sometimes wires Nos. 1 and 2 are reversed through care-

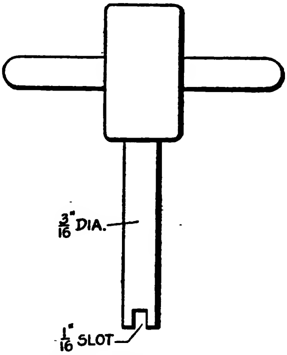


Fig. 451. Vibrator Adjusting Wrench

lessness or ignorance, and the battery current is applied to the magneto breaker, burning the insulation and annealing the breaker spring.

Bosch Type NU Magneto. The type NU operates on a principle distinctly its own, having no distributor gears and attendant parts. The primary circuit is the same as in the DU and has a similar breaker. The secondary winding is entirely insulated from the primary with both ends brought out to a slip-ring. This slip-ring is double and has two segments opposite each other on adjacent slots. This armature circuit is shown in Fig. 452. One end of the primary is grounded, and the other connects to the breaker. One end of the secondary connects to a one-ring segment, and the other to the opposite segment. Four brushes rub on these rings and distribute the current to the proper cylinders. The plug cables are attached through the center of the brush holder, and this holder is attached

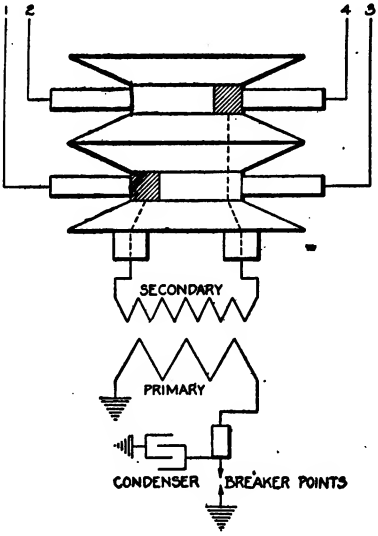


Fig. 452. Armature Circuit of Bosch DU Type

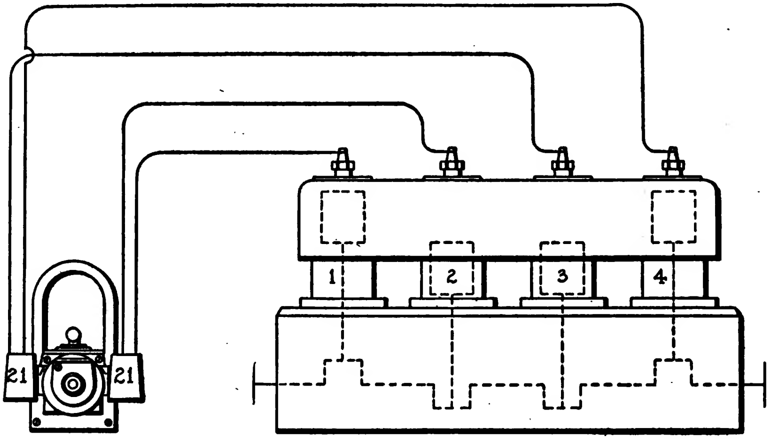


Fig. 453. Wiring Diagram of Bosch DU Type

to the magneto opposite the collector rings. As a four-cylinder engine fires every other revolution, No. 1 cylinder is at the firing point when No. 4 cylinder has just finished its exhaust stroke and is free of gas or pressure; hence a spark may occur in this cylinder with no effect. Therefore cylinders 4 and 1 may spark together with an explosion in 1 only; on the next revolution a like operation fires No. 4. Cylinders 2 and 3 have a like combination. The two spark-plug gaps are in series, and the ground completes the circuit between them, but as one gap is only under atmospheric pressure, it has practically no effect on the spark. The plugs should be set 0.025 inch on all cylinders.

The wiring is shown in Fig. 453. The magneto rotates at engine speed and can be used on a four-cylinder engine only. In testing the winding, a different procedure is necessary than with the ordinary type of armature. The armature is connected as in Fig. 454, the primary being connected to the single-break tester and the secondary leads being held $\frac{5}{16}$ inch apart. This may be done by driving two nails in the bench touching the ring segments and a gap placed between the nails; or if the slip-ring is removed, bend the wires together for a gap. With the spark jumping this gap, ground the lead *A* and note whether the spark ceases on the gap; repeat on lead *B*. If either ground cuts out the spark between the gap, the armature is broken down. This is the only reliable test for this type of armature. In case it proves defective pull the ring off as the ground may be in a punctured slip-ring; test again without the ring. Where too much oil is used, the brush holders become covered with oil and carbon dust which will afford the current a path, burning the ring and putting the magneto out of commission.

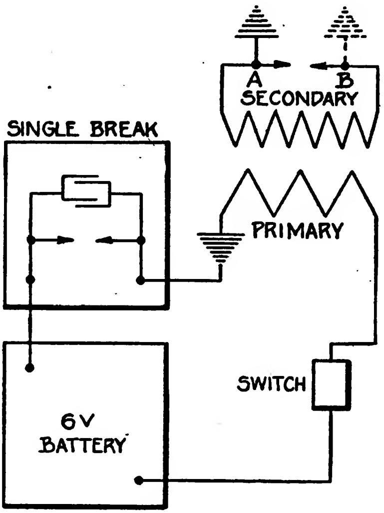


Fig. 454. Testing Bosch DU Type Armature

Bosch Impulse Starter. This impulse starter is built in, and operates in oil. To start the engine, move either by hand or by a dash control the lever on the side of the case to the side marked **ENGAGED;** return to neutral, as the starter is now set. Moving to **RELEASE** disconnects the starter. The impulse starter will

Fig. 455. Construction of Bosch Impulse Starter

operate until the engine starts and the speed reaches about 150 r.p.m., when the starter is automatically thrown out and remains inoperative. Fig. 455 shows the mechanism of this starter. A dish-shaped flange is mounted on the magneto shaft, on the edge of which are four slots, two for right-hand rotation and two for left-hand. The crossbar fitting into these slots is driven through springs—two compression springs and two short bumper springs.

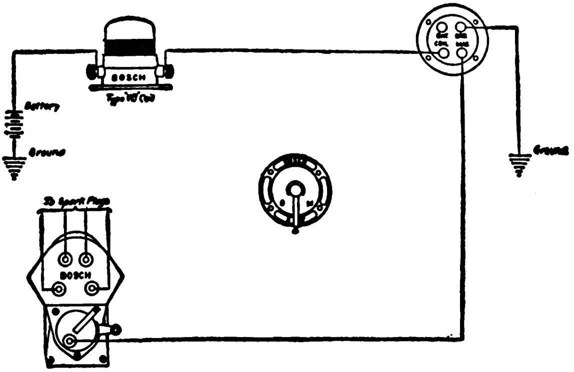


Fig. 456. Bosch Duplex Wiring Diagram

Carried on the starter drive shaft is a disc enclosing these springs and having two cams on its rim. The small pawl at the top is held away by a catch and released by the trigger handle on the exterior of the case. This pawl, when released, drops onto the driving disc and the crossbar when rotated and prevents the magneto shaft from turning, compressing the springs. The bar is released when the cam on the driving disc raises the pawl, and the compressed springs rotate the magneto armature, causing a spark in the cylinder. In changing this starter to opposite rotation, place the crossbar in the other slots, change the springs, reverse the pawl, and put in a new pawl shaft for opposite rotation.

Bosch Vibrating Duplex System. This system can be used with any Bosch magneto. It consists of a vibrator which is connected in series with a switch and the battery as in Fig. 456. The vibrator is of special construction to allow only enough current to be applied to the magneto primary to produce a good spark, without weakening the magnets, since there is no reversal of battery current through the armature as in a straight duplex system. The vibrator armature and platinum points are shown in Fig. 457. The upper bridge is of hard rubber, while the magnet pole pieces come very close together so as to make a very efficient magnet. A condenser, shown above the coil, is connected across the points. A switch turns off and on the battery or magneto ignition.

Fig. 457. Duplex Vibrator

The current from a battery—which may be 6 or 12 volts—or from 6 dry cells travels through the vibrator to the magneto primary and the magneto points which are together, and back to the battery through the ground. This causes the vibrating arm to vibrate, but as the magneto points are together no spark takes place as the current passes through them. At the instant the points separate, the current flows through the armature primary and a vibrating spark is produced, being timed by the action of the breaker points. The vibrator operates continuously, but louder while the magneto points are together. As soon as the engine starts, the magneto automatically comes into operation, producing a much stronger spark than the battery current.

Bosch Two-Spark Magneto. It is well known that in gasoline or any other explosive mixture the spark has a certain speed of propagation varying with the mixture. When ignited, the average air-and-gasoline mixture under compression requires about $\frac{1}{350}$ second to reach its maximum expansion and power, but as a crankshaft travel of 30 degrees takes place during this time, at a motor speed of 1000 r.p.m., a considerable lag is produced in the system. The electrical lag has been eliminated by using a magneto or a positive-break battery system. As the speed of propagation represents a flame speed of a certain number of feet per second, by cutting down the distance the flame must travel, we also cut down the lag of the explosion. This is done by using two sparks in the cylinder at the same instant. This system is most practical on the T-head motor. Fig. 458 shows how the distance of the flame travel is reduced, each plug starting the flame toward the center and practically reducing the lag by half, thereby giving a quicker explosion with a subsequent increase of power on the same charge and also obtaining greater speed and mileage.

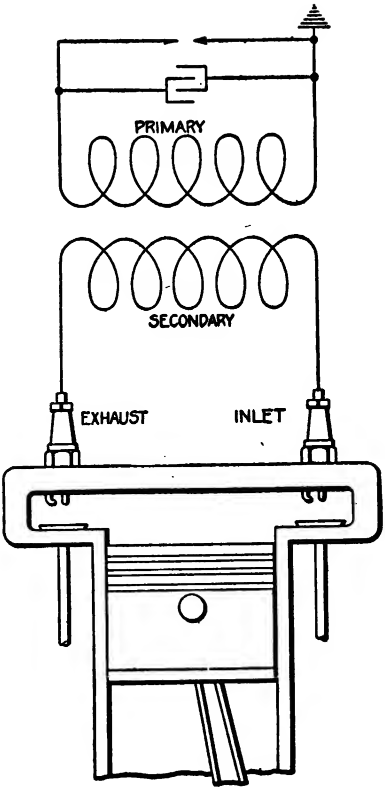


Fig. 458. Two-Spark Magneto Circuit

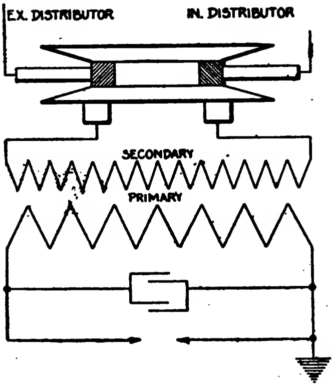


Fig. 459. Armature Wiring of Two-Spark Bosch

As the two plugs ignite the charge, the sparks must be simultaneous or the effect is lost. Therefore, the source of the spark must be the same at both plugs. This is effected by using one winding, Fig. 458; both ends of the secondary are brought out to a slip-ring with two segments, Fig. 459. The segments are on opposite sides of the ring and a brush bears on each, carrying the current to the distributors. These distributors are entirely separated from each other and are made in three pieces. A double distributor brush holder feeds them. The back distributor plate is fed from the rear and is connected to the spark gap by a wire lead to the right-hand brush holder, Fig. 460. The front distributor is connected to the rear safety gap and the left-hand brush holder. A switch is provided to turn the magneto off as well as to cut out one side of the ignition. When using one side only, the intake side is always used, as the inrushing gases keep the intake pocket free from burned gases, whereas the exhaust pocket will contain a small amount of gas and will cause a poor explosion. Fig. 460 shows the wiring for a Bosch two-spark independent system. The off position of the switch grounds the magneto primary, stopping the engine. No. 1 position allows the engine to operate on the intake side only, while No. 2 position allows it to operate on both sides. In starting with this system, it is best to use one side only, as the advanced timing obtained with the two sparks is likely to cause a kick back. When engines are hard to start, a dual system is used. A regular dual coil is connected as usual, Fig. 461, but instead of a jumper from the front distributor to the rear of the magneto, the coil is inserted in this line (wires *3* and *4* in diagram). A separate

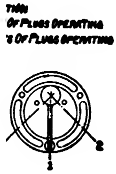


Fig. 460. Wiring Diagram of Two-Spark Magneto Ignition

Fig. 461. Wiring Diagram of Two-Spark Dual Magneto Ignition

breaker is used for the battery, as on the regular dual system, and a separate switch is provided to cut out one side of the ignition. It is marked *2-1-2*, the center position grounding the exhaust plugs, while either *2* position allows the motor to run on both sets of plugs. When starting on the battery, the intake plugs only are used.

The armature winding used on this magneto is similar to that on the type NU, Fig. 454, and on the newer type of two-spark magnetos, the windings are interchangeable with the NU. The older models have a slip-ring made in two pieces screwed together and are for R and L hand rotation. In taking apart this ring, care must be used not to break it; heating the shaft sometimes helps to free it.

To test the armature winding, proceed exactly as with the NU, Fig. 454, and the spark produced should be equal to it. When the winding is grounded on one side, it causes a poor running engine but not a regular miss, as it is firing on one side at all times. But when the miss is present on the intake side, the spark on the exhaust side, although good, does not produce a good explosion owing to burned gases, as previously mentioned.

Fig. 462. Setting Mea Distributor

Mea Type BK. The Mea magneto armature has the condenser and the slip-ring both placed on the same end, and the sleeve of the ring projects through the condenser. The breaker is operated by a fiber roller which strikes a flat steel cam located back of the breaker. The points are of platinum and should open 0.010 inch. The stationary screw should be locked in, as it sometimes works loose, cutting out the magneto. The magnets should test 25 on the magnetmeter. When charging, use the pole pieces in the charger and drill two small holes in the center of each to allow the dowel pins of the magnets to enter and obtain a flat contact with the magnet.

When reassembling the magneto, two methods are used for setting the distributor gear; Fig. 462 shows one method. The gear is turned so that No. 1 mark comes in the center of the window when the armature leaves the pole pieces $\frac{1}{16}$ inch. This will give the proper setting. The other way is shown in Fig. 463. A setting pin *a* is used, or a nail, which is placed in a hole *b* in the gear casing, and the distributor gear *c* is revolved until a like hole appears in line with the former hole. The armature *d* is then turned until a hole on its edge lines up with the other holes, and the assembly is then fastened together.

Fig. 463. Another Method of Setting Mea Distributor

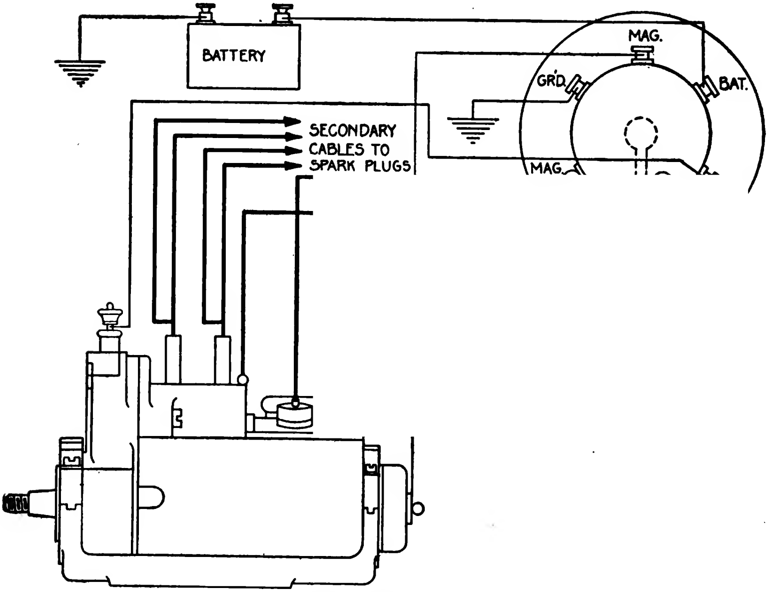


Fig. 464. Wiring of Mea Magneto Ignition

The cradle, or trunnion, holding the magneto becomes worn owing to oil and sand collecting on the exposed bearings and cutting them; as a result the whole magneto becomes loose and jumps around. When this happens, the cradle is fastened on the tool carriage of the lathe and a boring tool used to bore out the cradle bearings, taking care to maintain the original center line. The magneto end plates are next turned down and a brass or bronze bushing shrunk on and also pinned to prevent loosening.

Dual Type. When a battery is needed for starting, the dual system is used. A high-tension coil is mounted on the dash, the battery breaker then operating from the distributor shaft. The wiring is shown in Fig. 464. In the back of the coil is placed a vibrator, which interrupts the current. Therefore the spark is produced when the battery-breaker points on the magneto **make contact** and not when they **break** as in other systems. On the edge of the distributor gear is a mark which is lined up with a similar mark on the gear casing locating the firing point for No. 1 cylinder.

Mea Type A. This is an enclosed type and has the rocking part of the magnet assembly self-contained, the timing lever operating the advance. The timing of the distributor is done by meshing the marked teeth on the gears; and the gear housing is then slipped on. The breaker, Fig. 465, is of different design, the points being actuated by the fiber breaker block striking the steel cams and forcing open the points. When putting in new points, be sure that they line up and have sufficient pressure to keep them firmly together, but do not bend the spring too much as it will break. The armature is smaller than the BK type, otherwise it is the same. In testing, it should jump $\frac{5}{16}$ inch on the test gap.

Fig. 465. Mea Breaker

WESTINGHOUSE VOLTAGE REGULATORS

Description. The regulator consists of an E-shaped, laminated magnet, Fig. 466, which has three separate windings and is enclosed by a case through which the pole pieces project. On these pole pieces are two pivoted armatures; one armature, the cutout armature, controls the generator circuit to the battery; and the other, or regulator armature, controls the current output of the generator. The E-shaped magnet core provides a two-path magnetic circuit from the center core. Both the cutout armature and the regulator armature are pivoted over this center core, their outer ends overhanging the other extremities of the core, one armature extending to the right, the other to the left, Fig. 467.

Operation. It will be seen that when the generator voltage reaches a given value, at which the generator is intended to be connected to the battery circuit, the magnetism set up by the shunt coil (center coil, Fig. 466) is sufficient to pull down the cutout armature, closing the cutout contacts and connecting the generator to the battery. The charging current then flows through the series coil (right-hand coil) increasing the pull on the cutout armature so long as the generator is charging and pulling the points firmer together. When the speed of the generator falls below the generating point, the current reversing in a slight discharge through the series winding neutralizes the strength of the shunt winding and the points open.

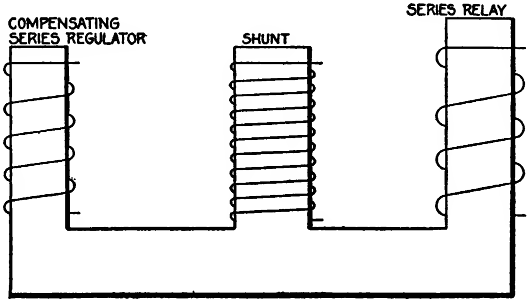


Fig. 466. Wiring of Westinghouse Voltage Regulator

As the generator increases in speed, the voltage increases with it, since the shunt winding of the regulator is connected across the generator brushes, Fig. 467. It increases its pull on the regulator armature, as the current delivered to the battery passes through the series coil of the regulator (left-hand coil, Fig. 468) and also exerts an additional pull on the armature, pulling down the armature and opening the points. This cuts in the regulator resistance coil, reducing the generator output; and as this reduction in current allows the armature and points to return, the operation is repeated. As the inductance of the shunt field prevents a sudden rise or fall of the field current, an average is maintained by the vibrating of the points. The resistance unit prevents sparking at the points, which, owing to the high self-induced current, would occur if the field were opened each time.

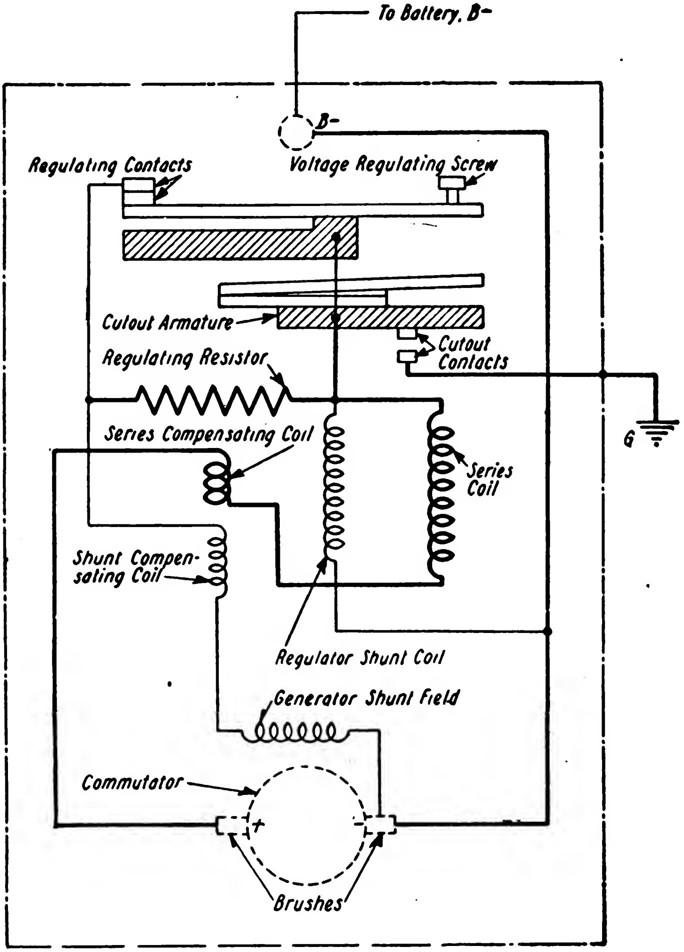


Fig. 467. Wiring Diagram for Westinghouse Generator with Self-Contained Regulator

The cutout points are silver; the contact made is slightly lateral owing to the offset pivoting of the armature, thereby maintaining an even surface. The same lateral movement is applied to the regulator points. The upper point is tungsten, and the lower, or movable point, is silver. As tungsten will not transfer itself to silver, the tungsten point should always be positive.

The adjustment of the cutout is made by bending the two prongs of the brass support located at the end of the cutout armature. Bending the tension-spring prong upward makes necessary a greater pull against the armature to draw it in, while bending the other prong adjusts the air gap between the armature and the pole piece. In setting the cutout, it should be adjusted close at the point where the generator will send a charging current of approximately 1 ampere to the battery and release at zero, or at not more than 1 ampere discharge. The air gap determines the cutting-in point—the smaller the gap, the quicker the armature will be attracted—and the spring determines the cutting-out point.

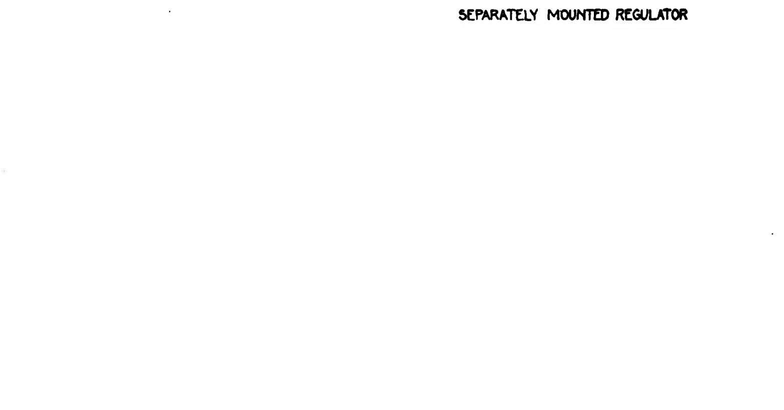


Fig. 468. Internal Wiring of Pierce-Arrow Voltage Regulator

The regulator is adjusted by means of a small adjusting screw at the top; this, when screwed in, raises the output. The points should be dressed smooth and perfectly flat on an oil stone, keeping them flat on the stone to ensure a true surface. Be sure that the armature is free on its pivots and that it does not come in actual contact with the pole pieces. Run the generator at its highest charging rate and turn down the screw adjustment until the ammeter shows 10 amperes.

Burning of the control points generally indicates an open circuit in the resistance unit, or if slight, it may be caused by an imperfect contact of points. When the regulator controls the output up to a certain speed and then ceases to regulate, the current rising above this point, it indicates a resistance unit of too low resistance. These units are interchangeable. When the tungsten point becomes rough and has a projection which fits into the silver point, causing sticking of the points, it indicates the wrong polarity of the points, the silver being positive and transferring to the tungsten under the influence of the current flow.

Westinghouse Voltage Regulator on Pierce-Arrow. This regulator is similar to the standard voltage regulator, but with a few additional changes. The points are bridged with a condenser in addition to the regular resistance unit, both being in multiple. This helps to prevent sparking. The standard resistance unit should be 30 ohms. It also contains a shunt compensating coil in series with the generator shunt field, which increases the sensitiveness of the regulation. This coil is wound on the regulator pole piece, Fig. 468, its purpose being to oppose the action of the series compensating coil, and it also helps in demagnetizing the regulator circuit and producing a quicker vibration with a subsequent even regulation. The setting is accomplished in the same way as in the standard regulator.

EQUIPMENT

Growler Armature Tester. This type of tester is the most efficient, and results are obtained quicker than by other methods. Several makes may be had. In selecting one, be sure that it has sufficient strength to do the work, as some of them are too small or have insufficient saturation to give results.

The principle of the *growler* is the same as that of the transformer, and it operates on alternating current, generally 110 volts. Fig. 469 shows a good design. The two coils *A* form the primary of the transformer; the frame and pole pieces *B*, the magnetic circuit, which is open. When an armature is placed between the pole pieces, the armature core completes this circuit. The armature conductors form the secondary winding, and if there are no short-circuits in the coils, very little current or voltage is induced in the windings, as in any transformer. Should there be a shorted coil, a heavy current is induced owing to the closed circuit of the short-circuited coil. This sets up a heavy vibration at the slot carrying the shorted coil, which can be felt, or heard, by placing a piece of thin steel or a hack-saw blade over the slot.

Operation. In testing, the armature is slowly revolved in the growler, and each slot is felt with the saw blade, as it comes to the top. If the armature is left on for a few minutes, the short-circuited coil will become hot and will eventually burn out. Commutator shorts due to small particles of copper dragged over the insulation when turning, commonly called "bugs," will be burned off by this heavy induced current. A poorly designed growler will not do this. In testing for an open coil, short-circuit each commutator segment in turn as the armature is revolved; each segment should give a spark owing to the induced current. In case of an open coil, no spark will result. In testing for grounds such as between the commutator and the armature shaft, a grounded winding will cause a spark.

Design. The following is an efficient design of growler that may be readily built in the shop, in case it is not desired to buy one:

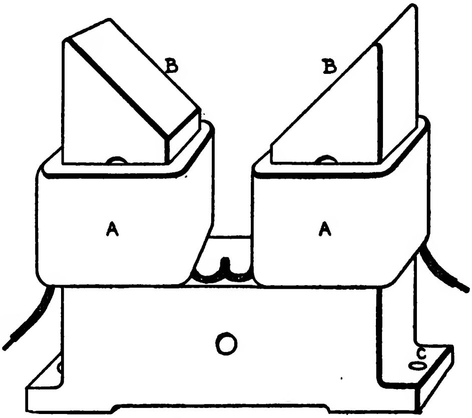


Fig. 469. Growler for Testing Armature

In Fig. 470 is shown a lamination of the proper shape and size cut from ordinary sheet iron and with three holes drilled for the holding bolts. There should be enough laminations to build up to a thickness of 2¼ inches, and the whole assembly should then be bolted together. Although sheet-iron laminations are the most efficient, the lessened efficiency of cast iron makes very little difference, as the growler is only used for a short time and the cast iron does not have time to heat.

To make the cast laminations, a pattern should be cut from ¼-inch pine to the shape of Fig. 470. The small lugs at the bottom are for the feet to bolt to the bench. The holes should be drilled after casting. The pattern should have three coats of shellac and should be sandpapered after each coat has been applied. Nine castings are necessary. Smooth up the castings on the sides and stack them together; hold them with clamps, then drill three ¼-inch holes through the whole assembly, as located in Fig. 470; and with the clamp still in place, rivet them together with ¼-inch iron rod. Do not set the rivets too tightly as the iron is likely to crack. Drill two ¼-inch holes in the legs, as at *C*, Fig. 469; these holes can be drilled from the bottom very easily.

The assembled frame can now be smoothed up on the emery wheel, especially the surface of the pole pieces *B*. The coils *A* are wound up on a wooden form, and each coil consists of 175 turns of No. 14 B.& S. gage copper magnet wire, each wound in the same direction. Leads should be brought out, using lamp cord. The coils are taped as shown in the illustration and are well shellacked. The two coils are placed on the frame, with the two inner leads at the same side; these two leads are connected together, and the two outside leads are brought out and connected to a 110-volt alternating-current circuit through a switch. As it is easy to forget to turn off the growler and as it makes no noise when there is no armature on it, it is well to connect a lamp in the circuit, Fig. 471, using a snap switch to turn it off and on.

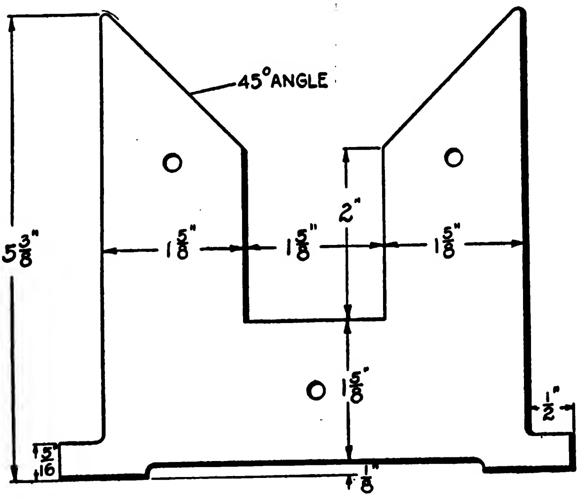


Fig. 470. Construction of Growler Lamination

Undercutting Machine. Most undercutting of commutators is done by hand with an old hack-saw blade and is both slow and unsatisfactory. There are several types of machines for doing this mechanically; some do a smooth job, but others take longer and give worse results than the hack-saw blade. The revolving needle gives excellent results and is the quickest of any type. Its adaptability to commutators of various sizes and to different conditions and its quickness in setting up make it very valuable. Its work is clean cut as well as uniform, with no scratches left on the

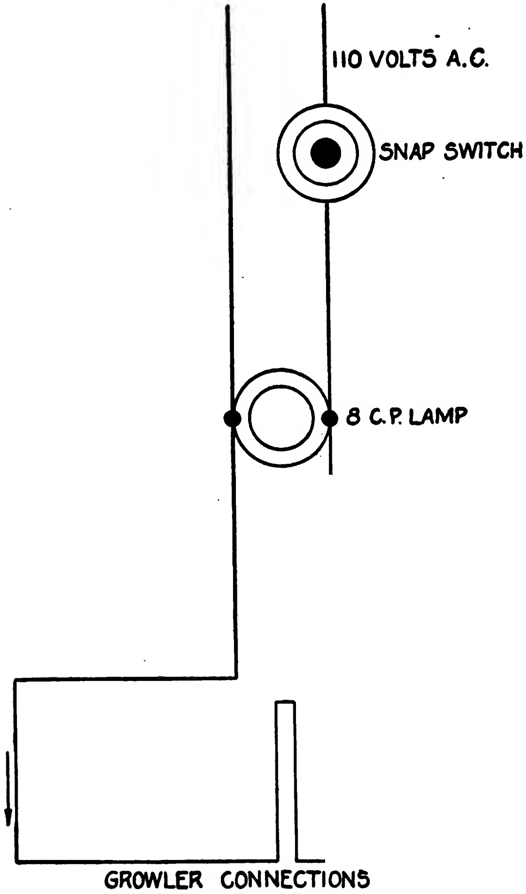


Fig. 471. Method of Wiring Growler

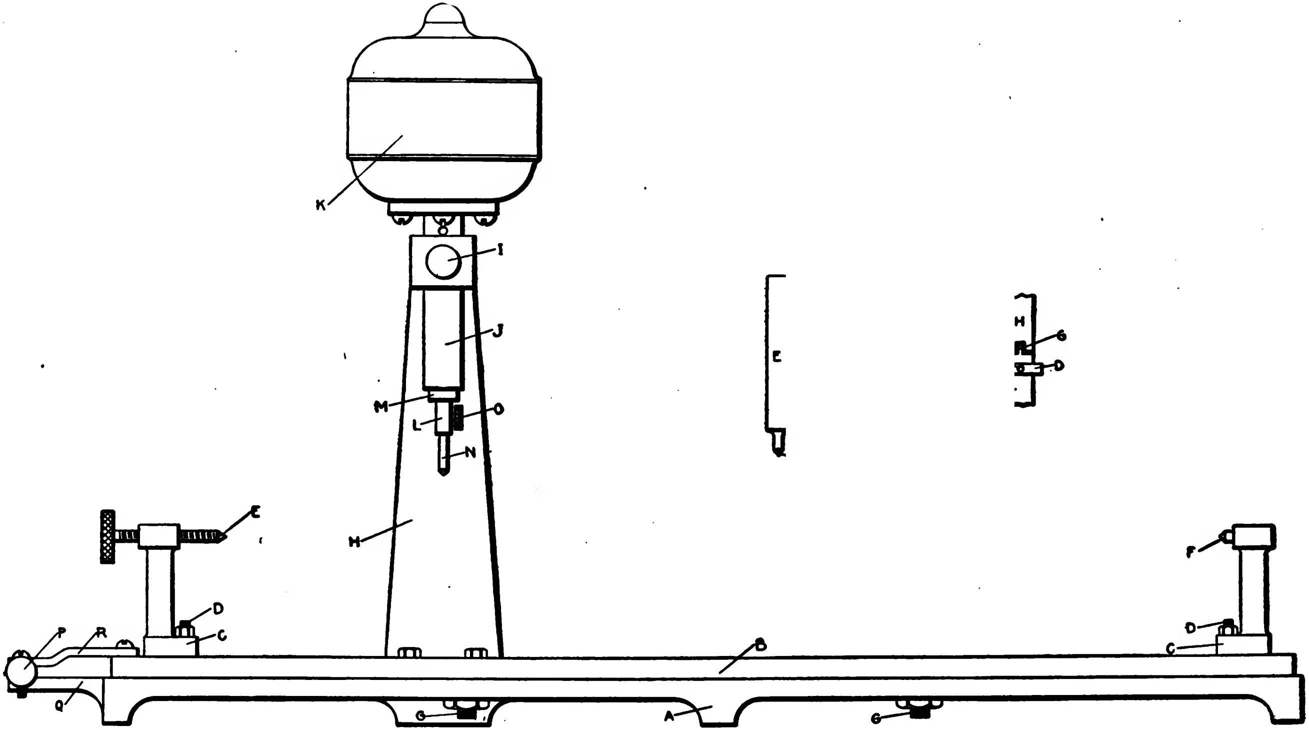


Fig. 472. Machine for Removing Mica from Between the Commutator Segments

commutator. A design for a machine of this type is given for those wishing to make one, as there are but few on the market at present.

Design. In Fig. 472 is given a side view of a motor-driven machine. The base *A* is made of cast iron 24 inches long, $5\frac{1}{2}$ inches wide, and $1\frac{1}{2}$ inches high; sliding on this base is a carriage *B*, made 3 inches wide and $\frac{5}{8}$ inch thick, which slides on rails cut on the base. Mounted on the carriage are two center brackets *C*; these are bolted on with the nut *D*. The center screw *E* is adjustable; the center *F* is solid. The column *H* holds the motor and cutter assembly. The motor *K* should be about a $\frac{1}{8}$-horsepower, 110-volt, high-speed universal type, using either

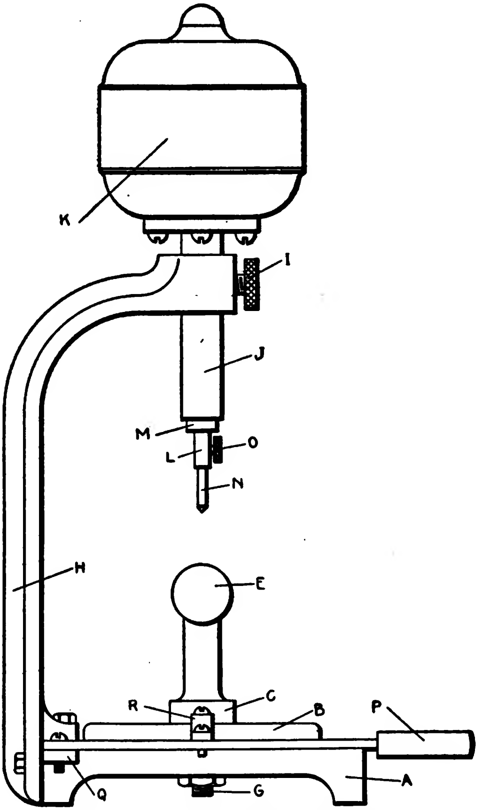


Fig. 473. End View of Mica Undercutting Machine

alternating-current or direct-current. The motor is mounted on the spindle *J* and is held in adjustment by the set screw *I* on the column. The needle *N* is held in the shaft *L* by the set screw *O*.

The armature is placed between centers, the spindle *J* is adjusted to the proper height, and the carriage is moved back and forth by the handle *P* through the linkage *R*, cutting out the mica to the required depth. Fig. 473 shows an end view. The column *H* is ribbed for strength and is fastened to the base, 8 inches from the end, with four $\frac{5}{16}$-inch standard cap screws, an extra wide leg being cast on the base to support it. The set screw *I* is $\frac{5}{16}$-inch S.A.E. thread and is knurled. The handle operating the carriage is of $\frac{5}{8}$-inch fiber, and the lever is hinged on the bracket *Q*, which is cast on the base. The bracket *Q* is $1\frac{1}{2}$ inches long and has a hole drilled and tapped for 10–32 screws; this bracket should be $\frac{1}{4}$ inch thick and $\frac{3}{4}$ inch wide. The base *A* has two rails cut on its top, the carriage *B* being planed to fit. These rails need not extend more than 6 inches on each end, as a lessened surface will reduce friction of the carriage. A bolt, or stud, is mounted rigid in the carriage, and a nut and washer hold it on; the slot should be slightly larger than the stud. The thread on this stud should be rather tight to prevent loosening, while the washer may be a spring or cupped washer to take up any variation in the machining.

The carriage also has a groove cut $\frac{1}{2}$ inch wide, extending within 6 inches of each end in the center of the casting. This is for the center standards *C* to slide in; by having both centers slide, any armature may be fitted quickly. The standards have a tongue which fits into the groove and is held by a $\frac{7}{16}$-inch carriage bolt with the head turned thin; the squared portion of the bolt prevents turning while adjusting. The rear center is solid in the standard, while the front center is adjustable. The knurled screw *E* should be of $\frac{7}{16}$-inch stock with an S.A.E. thread, both centers having a 60-degree taper.

The needle assembly, Fig. 472, consists of a spindle *A*, on which is mounted the motor *J* screwed to the flange. The shaft *B* is a piece of $\frac{1}{4}$-inch drill rod, which comes perfectly true and smooth. A collar *C* is pinned on with a $\frac{1}{16}$-inch pin *O*; the spindle is bored out to take two bronze bushings *P* and *Q*, which are pressed in and reamed to ¼ inch. An oil hole *I* is drilled to oil the upper bearing, the surplus oil running down the shaft and oiling the lower bearing. The shaft is placed in the spindle and a collar is pinned on at the top *D*. The detail sketch in Fig. 472 shows the end of the shaft, which has a tongue *G* fitting into a slot *M* in the motor shaft *H*, giving a positive, though flexible, drive.

The lower end of the shaft is drilled to take the needle *E*, which is held in by the knurled screw *F*. The needles are made of ⅛-inch drill rod, turned down and having a round shoulder *K* for strength, the lower shank being of various diameters, depending on the width of the slot to be undercut. It is best to make about three sizes of shanks. The point or cutting edge should be pointed and ground three sided, being careful to get each side the same and preserving a true center of the point. After the points are shaped, they should be tempered to a dull blue and finished with an oil stone. When the carriage is assembled on the base, place a little fine valve grinding compound and oil on the rails and grind in the surfaces to a smooth finish; this will ensure easy operation. Holes should be drilled in the base *A* and the machine fastened to the bench.

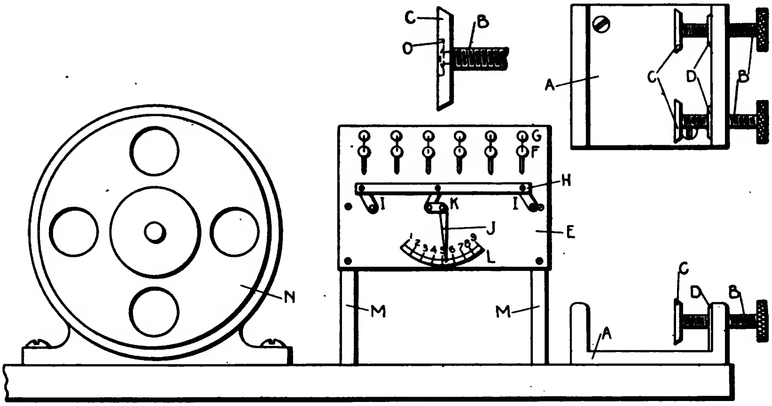


Fig. 474. Magneto Test Stand

Operation. To undercut an armature, place the armature between the centers, moving the centers so that the commutator will come under the needle, and screw up the adjustable center so that the armature will be fairly tight. Select the size of needle suitable for the width of commutator slot, lower the needle so that it will cut away about $\frac{1}{32}$ inch of mica, hold the armature steady with the slot opposite the needle, and steadily draw the needle into the slot, cutting a smooth groove the full length of the commutator; still holding the armature steady, withdraw the needle and cut the next slot, and so on. A little practice will make a smooth quick job. After all the slots are cut, place the armature in the lathe and take off the slight burrs with No. 00 sandpaper.

Fig. 475. Generator Test Stand

Magneto Test Stand. For testing magnetos, a substantial device that may be quickly set up is necessary. Fig. 474 shows a simple design for such an apparatus. The vise *A* holds the magneto to be tested, clamping it tightly by the two screws *B*. The magneto has a pulley provided with the standard taper, which is 5 degrees, or if a coupling is on the magneto that may be used for a pulley, a $\frac{3}{4}$-inch leather belt connecting this coupling with the motor pulley. The high-tension wires are connected to the adjustable spark gap, and the magneto is then tested. The motor *N* should be a variable-speed, 110-volt, and, if possible, direct-current machine. A starting box is used, taking the return spring from the handle and using it for a regulator. This will not damage the resistance, as it is only on a short time and the load is light.

The magneto vise should have a brass base *A*. The screws are $\frac{3}{8}$-inch S.A.E. thread with a knurled handle, a flat button *C* being riveted to the screw at the countersunk portion *O;* this prevents marring the magneto paint. The boss *D* on the base casting makes the threaded hole stronger. The spark gap is mounted on a fiber base *E*, $4\frac{1}{2}'' \times 6\frac{1}{2}'' \times \frac{1}{4}''$, fastened to the bench by the supports *MM*. The binding posts *G* are connected to the gap points *F*, which can be phonograph needles. The adjustable bar *H* is $\frac{1}{4}$ inch square, iron or brass, and swings on the links *II;* the indicator hand *J* moves on the dial *L* and is connected to the bar by the link *K*. These three links are made of $\frac{1}{16}'' \times \frac{1}{4}''$ iron. The link *K* is so made that when the hand rests on *I*, the points *F* should clear the bar $\frac{1}{16}$ inch, and the dial is laid off so that each calibration represents $\frac{1}{16}$ inch; this gives a quick adjustment. The link *I* on the right-hand side should be connected to the support *M*, which, in turn, is grounded to the vise *A*.

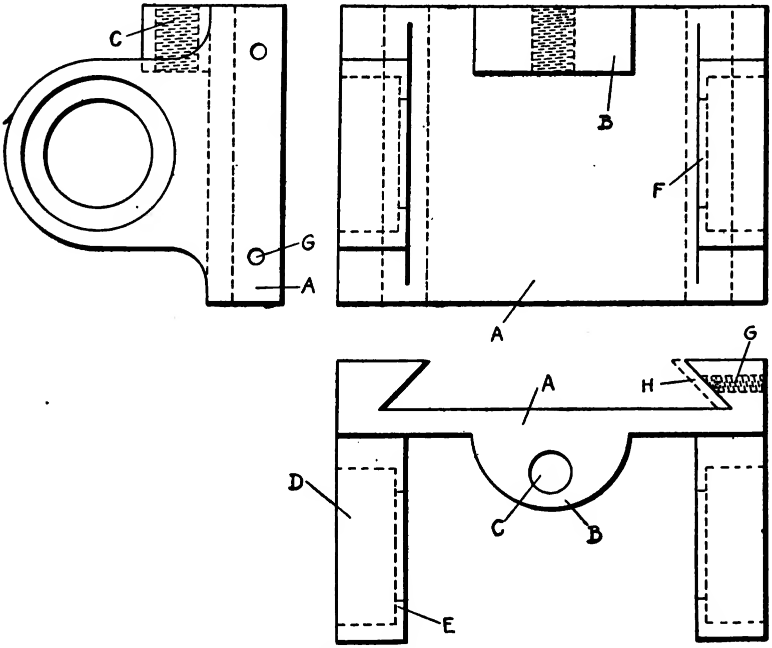


Fig. 476. Carriage of Generator Test Stand

Generator Test Stand. To test and regulate generators properly after repairing and before placing on the car, some means must be provided to run the generator at various speeds. Such a test stand must be universal and easily set up. A test stand meeting these requirements is shown in Fig. 475. The baseplate *A* is cast iron, 10″×16″, surfaced on the top. Column *B* is bolted to the baseplate and carries an adjustable head, which holds the driving assembly. The location of the column should be such that the center line of the chuck is in the center of the base. A threaded rod bent into a crank *G* raises and lowers the head; the rod should be $\frac{7}{16}$ inch with an S.A.E. thread. The lower end of the rod is turned with a $\frac{1}{4}$-inch shoulder and fits into a hole bored in the base; the upper end has a collar *J* pinned on, and the plate *K* takes the thrust in lowering the head.

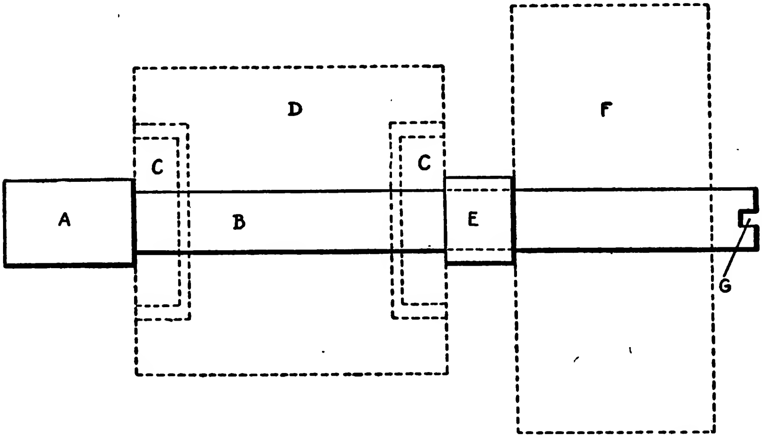


Fig. 477. Pulley Assembly for Generator Test Stand

The head has a 45-degree angle groove cut in the body of the casting, Fig. 476, which fits into a similar tongue cut on the column. One side of the body casting *A* has the groove cut away slightly more to make room for a gib *H* and two adjusting screws *G* to take up the wear in the head. These screws *G* should be 12–24 iron screws and should have lock nuts. The boss *B* is for the adjusting rod and is threaded to receive it. The shaft runs on two annular ball bearings, the head casting being recessed at *D* to a press fit while the shoulder *E* prevents them from working loose. The hole *F* is for the shaft and is slightly larger than the shaft, Fig. 477. *A* is the end that fits into the chuck collar; *B* is turned to a good light press fit in the bearings; the collar *E* is placed between the outer bearing and the pulley *F* and prevents the shaft from working out; the slot *G* is to drive the speed indicator; *CC* are the bearing seats; and *D* is the body casting. Between *A* and *C* and between *E* and *C* are two thin brass plates to keep the dirt out of the bearings.

The chuck *F*, Fig. 475, is a 4-inch, three-jawed, universal type, fastened to a flange and pinned to the shaft *D*. Any chuck will do for this, as being out of true will not make much difference. The speedometer is made from a Corbin-Brown head, and the scale should have an 80 m.p.h. limit. The hand is taken off and a blank glued to the old dial. The instrument is then recalibrated with a speed counter to read r.p.m. Having obtained this data on the blank, a neat dial may be drawn and glued on. The speedometer head is held on the carriage by an angle iron made of $\frac{1}{8}'' \times 3''$ iron, the coupling of the head fitting into the slot *G*, Fig. 477. Take care to line up the head so that the coupling will be free at all positions of the shaft. Having the speedometer always operative saves time in testing. The pulley *E*, Fig. 475, should be about 4 inches in diameter and with a 2-inch face, while the motor pulley *A* should be 6 inches.

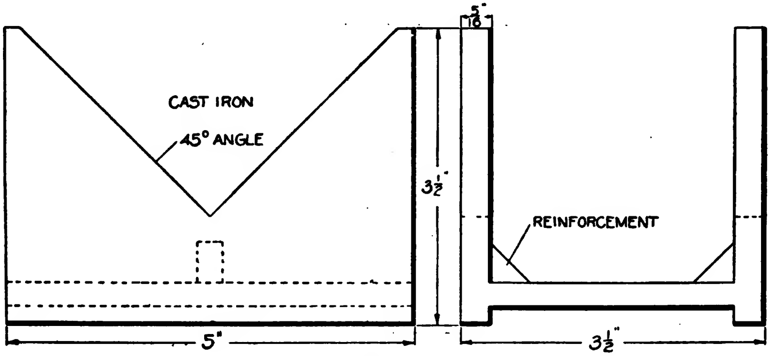


Fig. 478. Mounting Blocks for Generator in Test Stand

The generators are held in the stand by a motorcycle chain attached to the screw *M*, Fig. 475, and hooked onto a stud. It is tightened by the hand nut *N*, this screw sliding in a slanting guide *L;* this guide is about 8 inches long and allows for different sizes of generators. There are three studs to which the chain may be hooked. Holes are drilled in the base to fasten the generator to the bench. Square generators line themselves when

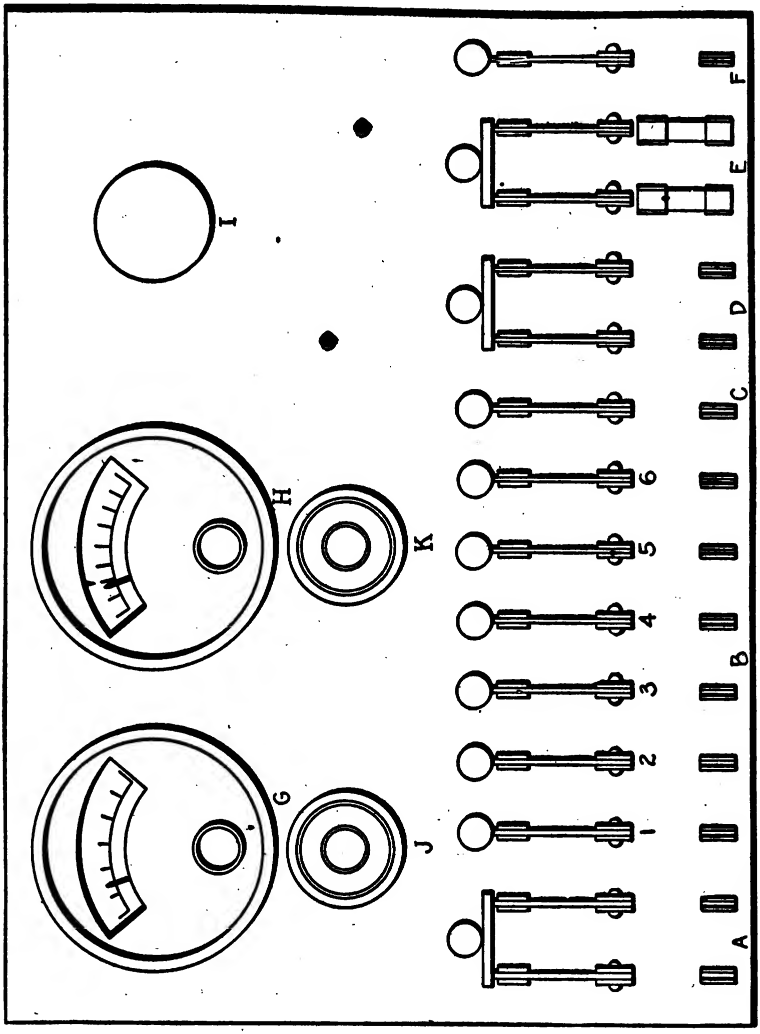


Fig. 479. Switchboard for a Generator Test Stand

placed in the stand, while round-type generators are placed in a V-shaped casting, Fig. 478. This is a simple casting requiring no machine work, the bottom edges being filed so that it will set flat on the baseplate.

The motor for the test stand should be a 1-h.p. variable-speed. A 110-volt direct-current motor is the most convenient and should have a control box of a wide variation in speeds. A 2-inch leather belt is used, no special adjustment being necessary on the belt as the movement of the head carriage is not sufficient to affect the tightness of the belt. When an electric speed indicator is desired, a small direct-current magneto generator is mounted in place of the speedometer and driven through a similar coupling; a voltmeter is then placed on the test board calibrated to read r.p.m. instead of volts. A reversing switch is necessary as the voltmeter only reads in one direction.

Generator Test Stand Switchboard. When testing a generator in the stand it is necessary to have an ammeter to show the charge rate and a voltmeter to show the voltage. The switchboard for this test stand is shown in Fig. 479. It is made of slate, or marble, and has two instruments at the top of the board; *H* is the voltmeter, which should be a double-scale instrument with the high reading 50 volts and the low reading 10 volts, switching from one to the other by an ordinary three-way snap switch *K*. If unable to get a meter of this type, an ordinary single-reading meter may have a tap brought out and connected in the meter resistance so as to give the low reading. The ammeter *G* should have a 50-ampere scale with a separate shunt; the shunt wires are reversed through the four-way snap switch *J* to read either charge or discharge on the meter.

As there is a great variation in the voltages of the different systems, it is necessary to have from 6 to 24 volts available. The double-throw switches *B* permit this. There are six switches and when all of the switches are down, the batteries are connected in parallel, giving 6 volts. When switches 1 and 6 are left open, 2 and 5 down, and 3 and 4 up, the two center batteries will be connected in series and the end batteries open, giving a 12-volt circuit. When switches 1, 2, 3, and 4 are up, 5 down, and 6 open, batteries 1, 2, and 3 are connected in series, leaving battery 4 open, giving 18 volts. When all switches are up, the four batteries are connected in series, giving 24 volts. The switch *H* cuts off and reverses the polarity of the battery circuit to the test clips *N*, Fig. 480. Switch *F* is used for detecting grounds and is connected to the 110-volt line through the lamp *I;* in the up position, one lead is tested, and in the down position, the other lead. The switch *C* is for grounding the leads and saves time in setting up.

Fig. 480. Reverse Side of Switchboard, Fig. 479, Showing Wiring of the Various Units

The motor operating the stand is controlled from the board, the switch *E* being fused and controlling the main current to the armature, while the switch *D* is a field switch and is reversible. The leads *N* from the switch *H* are the test leads and should have test clips attached; the leads from the switches *B* are the battery connections and lead to the four 6-volt batteries, the first terminals, −1 and +1, connect to the first battery, −2 and +2 to the second battery, and so on. The leads *Q* from switch *D* attach to the motor field, while the leads *P* connect to the armature. The leads *O* are from the 110-volt line and supply the test lamp *I*. The shunt *L* is used for the ammeter.

Ignition Switchboard. For quickness in operation, the single break must be connected so that any type of coil can be tested without using separate ballast coils or leads. This is accomplished by having everything on one switch, as shown in Fig. 481. The switch *A* has eight combinations: 220 volts in series with two 110-volt lamps *D* mounted in sign receptacles so that the lamps project through the board; 110 volts in series with one lamp; a battery contact which gives either 6 or 12 volts, depending on the position of the switch *E*. This switching of the battery current allows either voltage to be used on any of the other switch points. There is also a master vibrator; a single-break tester operated by the handle *C;* the same single break with a 0.45-ohm ballast coil in series; a 0.45-ohm ballast coil; and a 1.2-ohm ballast coil. An ammeter *B* shows the current used.

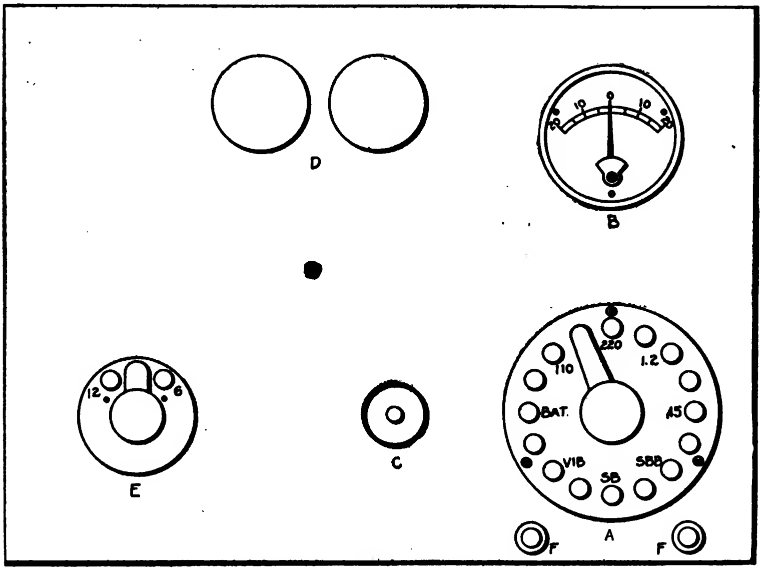


Fig. 481. Ignition Switchboard

In Fig. 482 is shown the wiring for the board. The switch *A* is connected to the various units and has the three ballast coils mounted directly on it. The single break *C* has a condenser *I* connected across the points; the master vibrator *G* also has a condenser *H* across the points. The terminal posts *J* connect to the battery and the terminals *K* to the 110- and 220-volt line. The posts *F* are the test leads and should have test clips attached to

Fig. 482. Reverse Side of Fig. 481 Showing Wiring of Ignition Switchboard

flexible cables. The whole board may be of wood and enclosed in a box frame, the front swinging on hinges.

The construction of the switch is shown in Fig. 483. The base *A* is made of ½-inch red fiber, mounted on a mandrel and turned in the lathe to a true circle. It is then placed in the chuck without the mandrel and the two sides faced off; sixteen 12–24 right-hand brass screws are then screwed into the base, Fig. 481. The base is again chucked and the heads are turned off to $\frac{1}{16}$ inch thick. These screws should be 2 inches long so as to extend through the switchboard. Every other screw is cut off flush on the back, as there is a dead point between each two contacts to prevent short-circuits in switching from one point to another.

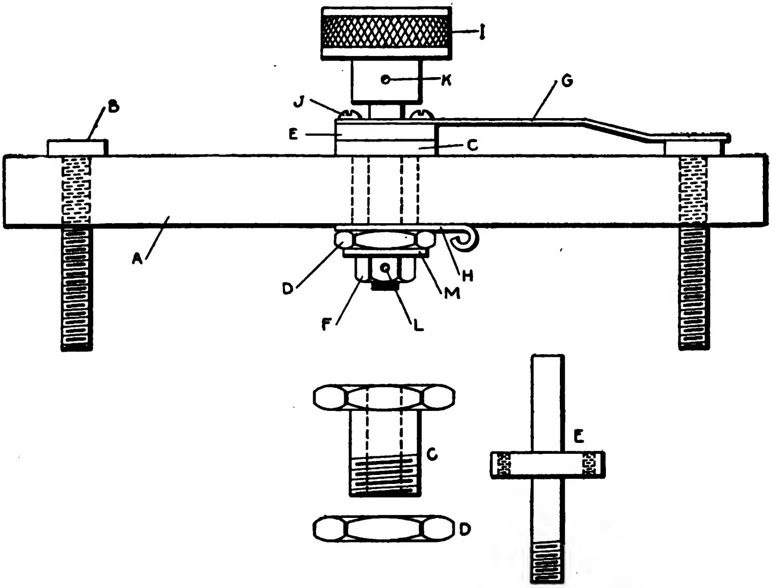


Fig. 483. Construction of Combination Switch for Ignition Test Board

A center sleeve is made for the switch shaft to rotate in. This is made from a ⅜-inch S.A.E. cap screw with the head and nut *C* and *D* turned thin and a ¼-inch hole drilled in it to receive the shaft *E*. The sleeve *C* is fastened in the base with a terminal clip *H* under the nut *D;* this is for the center connection. The shaft *E* has a blade of phosphor bronze *G* screwed to the flange with two 4–36 screws *J;* the shaft itself is held by the nut *F,* under which is a washer *M;* a pin through at *L* prevents the nut from working loose. A fiber handle *I,* pinned on at *K,* completes the switch.

Bearing Puller. There are several bearing pullers on the market, but they are not adaptable to every kind of job and are weak when it comes to a real hard pull. A practical puller is shown in Fig. 484. The base *A* is of cast iron, having a front vertical standard *J* and a boss *B* cast to receive the screw *C.* This screw is ¾ inch with a standard thread. A good snug fit should be made, as wear will eventually cause it to become slightly loose; the crossbar *D* is used in turning the screw. The plate *F* on the front standard is held on by two ⅜-inch cap screws and carries the clamp screw *G,* which holds the jaws together. The ribs are placed on each end to strengthen the base, and four holes are drilled in the base to bolt it to the bench. Fig. 485 shows the sliding jaws *H* and *I* which fit into a slot in the end standard *J;* the slot is cut from top to bottom. The top plate *F* carries the clamp screw *G* which is ⅜ inch with an S.A.E. thread; the lower end has a groove turned in it. This plate fits on the

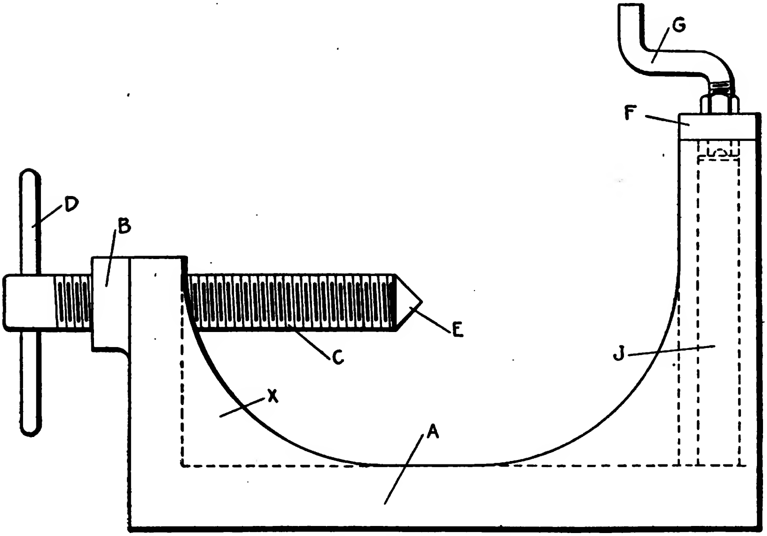


Fig. 484. Bearing Puller Side View

screw *G* and is held on the sliding block *H* by two 8–32 screws. The block is counter bored to allow the end of the screw to turn free; this device is to raise the block in changing jaws.

The sliding blocks are shown in Fig. 486; these blocks are cut away, as shown, to receive the jaws, which are held by the two small pins *M*. In recessing the blocks, place them in the lathe with a piece of $\frac{1}{8}$-inch metal between them at *W;* this will make it possible to tighten the jaws in place. The jaws used to grip the bearing are shown in Fig. 487 and should be made of steel, either tool or cold rolled, and case hardened. They are made of round stock of the proper outside size, cut off in lengths, faced off, bored out at *P*, and turned round in the chuck with the shoulder *R*. The jaw face at *Q* is bored and rounded to fit the face of the

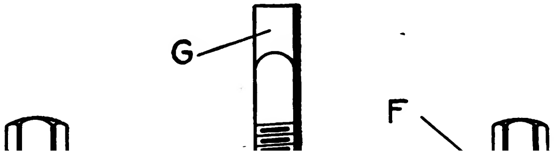


Fig. 485. Bearing Puller End View

bearing. The jaws are made for several sizes of bearings, a different set of jaws being made for each, such as 12-millimeter, 15-millimeter, 17-millimeter, etc. The only change in any of these jaws is the size of the face *Q*. Make the jaws for the largest bearing first and then make up the rest the same, with the exception of the face *Q*. After the jaws are machined, the holes *O* are drilled and the finished ring is cut in half as at *S;* this can be done in a milling machine or with a hack saw.

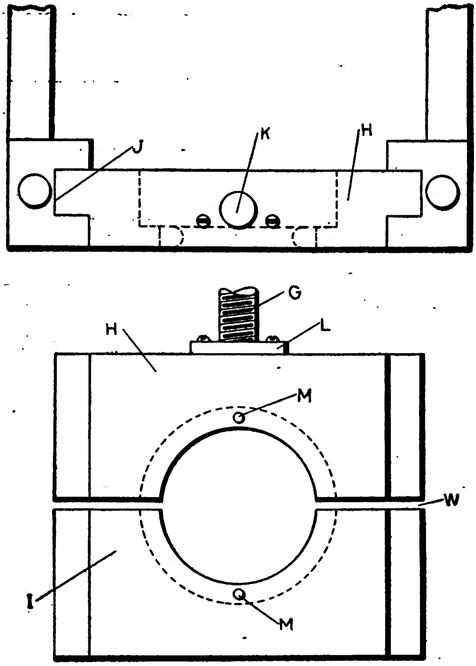


Fig. 486. Assembly of Bearing Puller Clamps

As the push rods used in pulling the bearings turn and burr the work, an end piece or point is made, Fig. 488. This end piece *E* is made of tool steel and hardened. The screw *C* is drilled as at *T*, and a ball-bearing *U* is placed in the hole the end piece rests on. This ball takes the thrust, allowing the end piece to turn. As the screw cannot be used against the work, the push rods shown in Fig. 489 are used. These are made of ¾-inch cold-rolled steel with different shaped ends; *A* is used for general work,

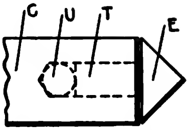


Fig. 488. Free Center

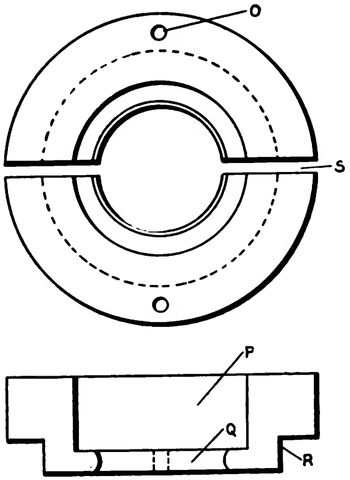


Fig. 487. Bearing Puller Clamps

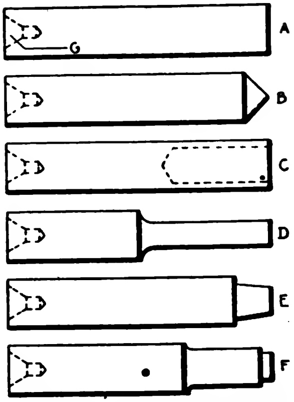


Fig. 489. Push Rods for Testing Generators

Fig. 490. Handy Electrical Work Bench

B for shafts with centers, *C* is hollow and fits over magneto drive shafts to protect the threads, *D* is for small bearings, *E* is for Bosch breaker end bearings and *F* is for Eisemann breaker end bearings. Various other shaped rods may be made to meet requirements. These rods should all be case hardened. In using the puller, the bearing is placed in the proper sized jaws and screwed down with the clamp screw, the proper rod being used to push off the bearing.

Work Bench. To work with neatness and precision a neat and handy one-man bench is required. It helps create the right atmosphere as a dirty and disorderly shop is sure to produce poor workmanship. Where the benches are separate, no workman is crowded, and the tendency to keep the shop clean is greater. A very convenient bench of this type is shown in Fig. 490. This is made of dressed pine, the top being of 2″×12″ planks two wide; the legs *B* and the crosspieces *C* and *D* are 2″×4″ with the top of the bench 32 inches from the floor. A crosspiece *E* is placed for a foot rest, the other half of the bench being used for the drawers *J*. The bench has a back *F*, 18 inches high with a shelf *G* of 8-inch board. To the left is a tool cupboard with a locking door *I*. On the board back *F* are hung the tools that are used most. The portion of the bench used for work should be covered with 28-gage sheet steel. The gas furnace can be placed at the extreme left. The test switches and lights can be placed at *H* on

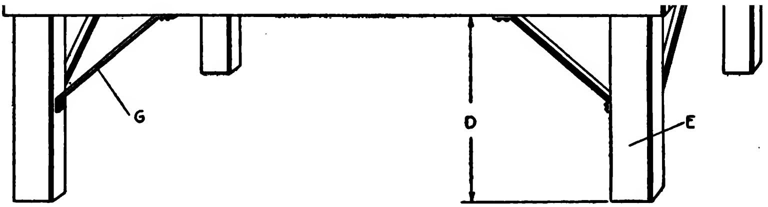


Fig. 491. Wash Rack for Cleaning Generator Parts

the end of the cupboard, the wires being run inside the cupboard. These benches may be used singly or built double with a right and left unit to fit between a window.

Wash Rack. A serviceable wash rack is shown in Fig. 491. This is placed wherever convenient and a pail is set under it to catch the drip. The sides *C* and the bottom are made of 1-inch pine; the legs *E* are 2″×4″. The iron brackets *G* support the legs, which may be any desired height. The length *A* should be 3 feet, and the width *B*, 18 inches; if made too large the rack collects trash. The inside is lined with 28-gage galvanized iron with a drain hole at *F*. Some shops put casters on this rack and move it from bench to bench.

Small Tools. As the gaskets used in insulating magneto bearings are sometimes hard to get, a punch to make them is shown in Fig. 492. The handle of the punch *A* may be made of tool steel or of soft steel with a steel cutter. A groove is cut at *C* to form an edge *B*, while the center is turned out at *D*, leaving two cutting edges to form the gasket. By relieving the cutting edges on the outside, it makes a clean-cut gasket. In order to get the finished gaskets out of the punch, an extractor is placed in the slot.

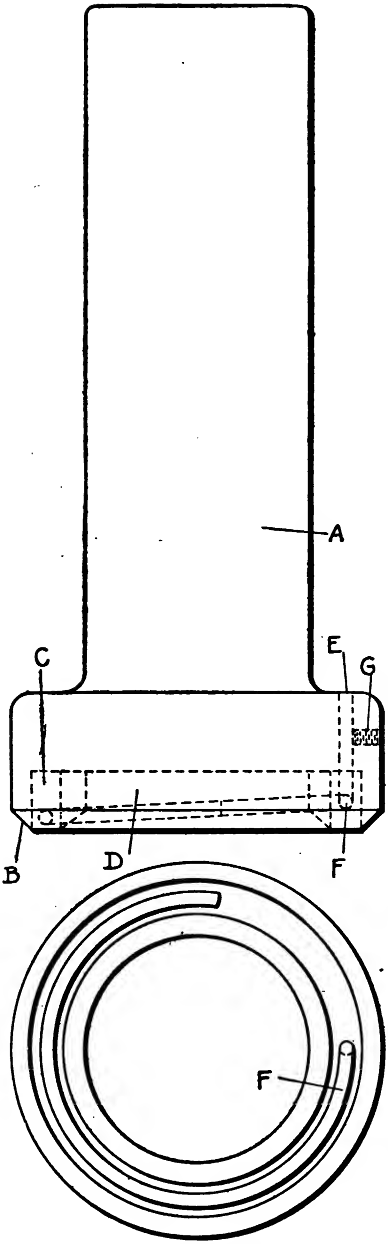


Fig. 492. Gasket Punch

The hole *E* is drilled, and a wire circle *F* is placed in the hole and is held by the set screw *G;* this wire is bent so that it will force the gasket out as soon as the pressure is taken from the punch. There are several sizes of these gaskets, such as insulation for 12-, 15-, and 17-millimeter bearing cups, and shims for the same sizes, the 15-millimeter being used the most.

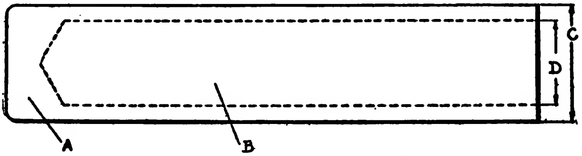


Fig. 493. Cone Bearing Drift

Cup Drift. In Fig. 493 is shown a drift for driving on cone bearings. The body *A* is made of cold-rolled steel of the size needed for the drift. It is drilled out at *B* to the desired size; the dimensions *C* and *D* should be to fit 15-millimeter and 17-millimeter bearings. As these are very handy tools around the shop, a variety of sizes should be made.

Bearing Cup Puller. As it is very hard to get a bearing cup out of an end plate, such a puller as shown in Fig. 494 is quick and efficient. The body *A* is made of cold-rolled steel, the lower end being shaped to a sharp angle and slotted so that it will expand. These slots *B* may be milled or cut with a hack saw. A $\frac{7}{16}$-inch hole *C* is drilled and threaded with an S.A.E. thread, and a taper bolt *D* is screwed into the hole. This screw has a taper *E* which expands the body of the puller, a flattened portion

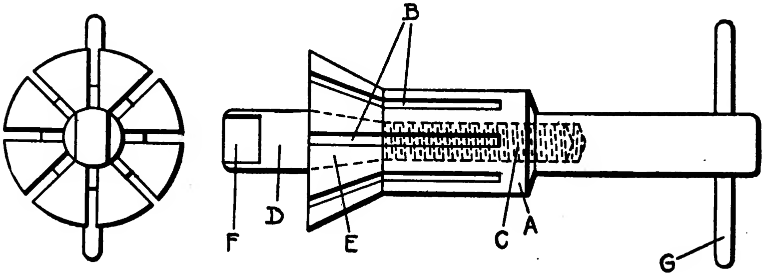


Fig. 494. Cone Puller

F being made for a wrench. A T handle is placed in the shank at *G*, and the whole tool is case hardened. In using this puller, the screw is backed out and the sharp angle points placed back of the cup. The screw is then turned up tight and the whole assembly struck sharply on the bench, striking the screw, when the cup will be forced out without damaging the cup or the end plate.

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